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SILVER ANNIVERSARY

PROCEEDINGS

25th Ontario Industrial Waste Conference

June 18 - 21, 1978
The Prince Hotel
Toronto, Ontario

TD
897.5
057
1978
MOE

Ontario
Ministry of the Environment
Hon. Harry C. Parrott, D.D.S., Minister
K. H. Sharpe, Deputy Minister

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Proceedings : 25th Ontario
inudustrial waste conference
(June 18-21, 1978) /

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P R O C E E D I N G S

OF THE

TWENTY - FIFTH

SILVER ANNIVERSARY

OF THE

ONTARIO INDUSTRIAL WASTE CONFERENCE

HELD AT

THE PRINCE HOTEL

JUNE 18 - 21, 1978

SPONSORED BY THE

ONTARIO MINISTRY OF THE ENVIRONMENT

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PREFACE TO THE PROCEEDINGS OF THE ONTARIO INDUSTRIAL WASTE SILVER ANNIVERSARY CONFERENCE

The 25th Ontario Industrial Waste Conference marked 25 consecutive years of technical paper presentations on multiple subjects related to industrial waste abatement. In that time the Conference has grown in stature and international reputation as one of the best sounding boards for innovative answers to weighty problems in a specialized field of environmental control. Following are the texts of the papers presented at the 25th Conference.

But the highlight of the Silver Anniversary was a most successful banquet staged during the Conference which brought together the principals who founded and continued the annual sessions. Dr. A. E. Berry, Dave Caverly, and Ken Sharpe were all there, as well as Mae Grove, Len Tobias, Merl Cathcart, and Fred Voege. Data on the historical significance of the Conference, the script used for the staged presentation, an overall report reprinted from the August issue of Water & Pollution Control, and extracts from the Conference program are all incorporated in this Proceedings issue to commemorate the significant occasion. The anniversary celebration was well received with all delegates receiving a souvenir paperweight appropriately customized to record the event.

The calibre of papers, and the co-ordinating expertise of the session chairmen, was as high as ever for the 25th Conference. The Planning Committee appreciates the work, thought, and attention each of the speakers gave to their part in the program. Because of this, all sessions were well-attended by the 500 delegates at the Conference.

It has been my pleasure to act as Conference chairman for the past two years. It was a special privilege to be chairman for the Silver Anniversary. My thanks to all those who were involved in the planning and execution of the 25th. The Technical Program Committee is particularly to be complimented on the execution of their role in obtaining excellent papers, knowledgeable speakers, and competent session chairmen. Without contributions such as these, our Conferences would not be the success they are.

The Ontario Ministry of the Environment plans to continue with its Industrial Waste Conferences as long as there is evident support and need for these collective deliberations. The 26th Conference will be held at the Prince Hotel in Toronto, June 17 - 20, 1979. You are invited to attend.

D. P. Caplice

D. P. Caplice
Conference Chairman

A Silver Anniversary with polish

By Tom Davey

The Ontario Industrial Waste Conference celebrated its Silver Anniversary with an expert blend of nostalgia added to its usual array of technical and scientific expertise.

It says much for Ontario's pioneer environmentalists that they had the foresight to focus on industrial contamination 25 years ago, when it was but a fleeting concern in a society overwhelmingly dedicated to GNP growth.

Luckily, there were determined men who were there to take up the neglected cause of pollution in general and industrial pollution in particular.

There are those, of course, who are scornful of the province's record of environmental management. Such people naively assume that complex toxic problems — accrued over decades — can be made to disappear at a wave of the legislative wand to give us a pristine Disneyworld by the weekend.

But the experts, the people who make their living solving ecological problems instead of carping about them, know that remedial measures can only be achieved by the unremitting efforts of dedicated scientists and engineers.

At the 25th conference, Dennis Caplice and Len Tobias traced the history of the OIWC in a beautifully-timed dual presentation laced with humour and nostalgia.

Flashback to one of the early OIWC days when a youthful Dennis Caplice entertained delegates. For two consecutive years he has been conference chairman and is now one of the most respected figures in the environmental field

Showing surprising show biz flair, they interlaced narrative with song and dance interludes with the spectacular Bert Rankin group and the Nite Star Dancers.

The first OIWC was sponsored by the Pollution Control Board of Ontario, a body of civil servants appointed by the late Leslie Frost, then Premier of Ontario. Even then, the board recognized that industrial wastes were an emerging problem in the environmental field.

Thanks to pioneers like Dr. Albert Berry, the first chairman, the foundations for an effective industrial treatment program were laid at the initial conference, held in 1954 at the Ontario Agricultural College in Guelph.

The conference later moved to the Delawana Inn at Honey Harbour, where it stayed for eight years before moving to the Bigwin Inn in the Muskokas.

It's now part of the folklore that one year the organizers found that the sewage treatment plant serving the hotel was not working well one year. Dave Caverly, then chairman of the meeting, selected a body of men to test the water and correct the fault.

Honour was at stake. There was simply no way a non-operating sewage treatment plant could be tolerated during a conference organized by the Ontario Water Resources Commission.

As the annual event grew in stature, it attracted people from other provinces, as well as the United States,

Dave Caverly, one of the dominant personalities behind the OIWC, chats with a guest at the annual banquet

Dr. J. D. Norman (left) with Environment Ontario's Deputy Minister K. H. Sharpe

so it moved to Niagara Falls from 1966 to 1971.

Old timers will recall with glee that food poisoning struck one meeting there. At first many registrants were mystified by the abrupt departure of attendees during sessions, before they themselves were smitten. The problem, as well as the problem-solvers, attended that particular meeting. Dennis Caplice recalled that the Niagara Falls sewage treatment plant was overloaded for a period of 12 hours.

In 1972, the OIWC moved to Toronto, where it has stayed until the present time. The nostalgic review then honoured the people who had contributed to it over the years.

In reviewing the technical program, the transformation of the environmental scene over the past 25 years becomes evident. New levels of sophistication have been attained. With one entire session devoted to nuclear waste problems, plus papers such as The Role of Economics in Environmental Strategies, Acidic Precipitation, and the Phytotoxicology Fluoride Studies in Ontario, it is clear the organizers cast a wide interdisciplinary net when they assembled their program.

The pioneers of OIWC, many of whom were present at the Silver Anniversary, can indeed be proud of their 25 year old progeny.

Dennis Caplice (left) with Mae Grove and Dr. J. Vance

Those honoured during the Silver Anniversary Banquet for their contributions over the years were:

Dr. A.E. Berry	Jim Duncan
D.S. Caverly	Min Yatabe
K.H. Sharpe	Bob Parker
Mae Grove	Dr. J.D. Norman
L.M. Tobias	Bill Swarm
M.J. Cathcart	Sid Dutton
F.A. Voege	Bill Case
Dennis Caplice	Hugh Fielding
John Patterson	Dick Millest
Ed Turner	J. Root
Dr. J. Vance	M. Cheetham
Hon. G. McCague	Hon. J.A.C. Auld

Dr. A. E. Berry, first chairman of the OIWC

J. A. McCoubrey at the technical sessions

ONTARIO SILVER ANNIVERSARY INDUSTRIAL WASTE CONFERENCE
JUNE 18-21, 1978, TORONTO

25th Ontario Industrial Waste Conference Honors Pioneer Delegates and Founders — A montage of those honored at the Silver Anniversary Banquet during the Conference on June 20, 1978, at the Prince Hotel in Toronto. **Left to right, top row**: D. S. Caverly, Conference secretary 1954-1962 and chairman 1963-1973; Mrs. and Jim Duncan, who participated in Conferences even before the first attendance records of 1958; K. H. Sharpe, chairman 1974-1976; Sid Dutton, who has attended all 25 conferences; D. Caverly; Bob Parker, a delegate since 1959. **Second row,** standing: Hon. J. A. C. Auld, former Ontario Minister of the Environment; Bob Parker; M. J. Cathcart, conference co-ordinator 1974; Mr. and Mrs. Ken Sharpe; J. H. H. Root, retired MPP for Wellington-Dufferin and former chairman of the Ontario Water Resources Commission, and Mrs. Root. **Third row,** seated: Dr. James A. Vance, former OWRC chairman; Mrs. D. S. Caverly; Mrs. R. R. Parker; Jack Scott, conference promotionalist for 15 years, and Mrs. Scott; Hon. George R. McCague, Ontario Minister of the Environment during the 1978 Conference, and Mrs. McCague. **Fourth row:** E. W. Turner, member of the Conference Planning Committee from 1976 to 1978, and Mrs. Turner. **Fifth row:** Jack Scott; Dr. A. E. Berry, first and continuing conference chairman from 1954 to 1962; Dr. Vance; Jim Duncan receiving an engraved sterling silver commemorative letter opener from Silver Anniversary Conference chairman Dennis Caplice; long-time delegate Dick Millest; Dr. Berry. **Sixth row,** standing: Mrs. Sharpe; Jack Norman, a regular conference delegate since 1960; Hugh Fielding, another long-time delegate; Mae Grove, the charter and continuing conference co-ordinator from 1954 to 1962; Mrs. Millest; Murray Cheetham, conference co-ordinator from 1975 to 1978; L. M. Tobias, conference co-ordinator 1963-1973; Mrs. Tobias; F. A. Voege, program convener for the conferences from 1960 to 1973. **Seventh row,** seated: Dr. Berry; Mrs. J. Patterson; J. B. Patterson, conference program convener from 1974 to 1978; Dorice Caplice, co-convener for the ladies' program for the Silver Anniversary Conference; D. P. Caplice, conference chairman in 1977 and 1978; Mrs. Yatabe; Min Yatabe, a conference regular since 1959; Mrs. Voege. Insert: Hon. James Auld. **Bottom row:** long-time delegates Bill Case and Bill Swann; ladies' program co-convener Jane Reid.

CONFERENCE PLANNING COMMITTEE

Conference Chairman
D. P. Caplice, Director
Environmental Approvals Branch
Ontario Ministry of the Environment

Program Convenor
J. B. Patterson, Supervisor
Industrial Approvals Section
Environmental Approvals Branch
Ontario Ministry of the Environment

Conference Co-Ordinator
M. F. Cheetham, Co-Ordinator Regional
Information Programs,
Information Services Branch
Ontario Ministry of the Environment

E.W. Turner, Manager, Waste System
Planning, Waste Management Branch,
Ontario Ministry of the Environment

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T. D. Armstrong, Manager, Industrial Abatement, Central Region, Environment Ontario
E. T. Barrow, Head, New Technology Unit, Air Resources Branch, Environment Ontario
B.I. Boyko, Head, Technical Evaluation Unit, Waste Utilization Section, Waste Management Branch, Environment Ontario
J. R. Hawley, Head, Mining & Metallurgy Unit, Pollution Control Branch, Environment Ontario
R. C. Stewart, Manager, Technical Support, West-Central Region, Environment Ontario

ONTARIO INDUSTRIAL WASTE CONFERENCE HISTORICAL DATA

Locations	Dates	Sponsor
Ontario Agriculture College, Guelph	1954-55-56	Pollution Control Board of Ontario
Delawana Inn, Honey Harbour	1957 to 1963	Ontario Water Resources Commission, Water & Pollution Advisory Committee
Bigwin Inn, Lake of Bays	1964 - 1965	Ontario Water Resources Commission, Water & Pollution Advisory Committee
Park Motor Hotel, Niagara Falls	1966 - 1967	Ontario Water Resources Commission
Sheraton Brock Hotel Niagara Falls	1968 to 1971	Ontario Water Resources Commission
Skyline Hotel, Toronto	1972 to 1974	Ontario Ministry of the Environment
The Prince Hotel, Toronto	1975 to 1978	Ontario Ministry of the Environment

Conference Chairman	Dates	Secretary/Co-Ordinator
Dr. A. E. Berry	1954 to 1962	D.S. Caverly/M. Grove
D. S. Caverly	1963 to 1973	L.M. Tobias
K. H. Sharpe	1974 to 1976	M. J. Cathcart (1974)
D. P. Caplice	1977 & 1978	M.F. Cheetham (75-78)

Program Conveners

1960 - 1973 F. A. Voege
1974 - 1978 J. B. Patterson

WELCOME

To the Silver Anniversary of the Ontario Industrial Waste Conference. Who would have thought 25 years ago when the first Conference was held on the campus of the Ontario Agriculture College in Guelph that we would still be going and getting bigger and better every year. Today the Industrial Waste Conference, sponsored by the Ontario Ministry of the Environment, has an international reputation of bringing together the leading experts in the field of industrial waste abatement.

Over the years the Conference has grown in stature because of the foundations laid by its originators in 1954. Dr. A.E. Berry was the first Conference chairman and continued in this capacity until 1962. During those years he was assisted by D.S. Caverly as secretary, Mae Grove as co-ordinator, and the late A. V. DeLaporte, who is credited with originally conceiving the idea of an Ontario Industrial Waste Conference. Dave Caverly succeeded Dr. Berry as Conference chairman for the next ten years, assisted by L. M. Tobias as co-ordinator. In 1974 K. H. Sharpe took over as chairman, assisted in that year by M.J. Cathcart as co-ordinator, and subsequently by M.F. Cheetham. Mr. Sharpe resigned his chairmanship in 1977 to assume weightier Ministry responsibilities and was succeeded by myself. From 1960 to 1973 the program convener was F. A. Voege, who was succeeded by J.B. Patterson who continues through to this Silver Anniversary. In the Conference's 25 years, there have been only four chairmen, five secretaries or co-ordinators, and two program conveners — quite an accomplishment for so few dedicated individuals.

Add to this the contributions of the members of the Technical Program Committees and the dedication of Conference delegates, and one can easily see why we are celebrating our Silver Anniversary. In essence, the success of the Conference has been due to a combination of persons, the Conference Planning Committees, the Technical Program Committees, the many speakers and session chairmen who have given of themselves and their talents when taking part in our sessions, and the repeat attendance and enthusiastic support of our delegates. Without this combination we would not be here in 1978. I would especially like to recognize those delegates who have been here before — and some have attended all 25 Conferences — and welcome those who are joining us for the first time.

The subjects of this year's Conference are in keeping with the challenges of the times. Economics and the environment, nuclear and toxic waste management, air and wastewater pollution control technologies — topics which are of vital concern to the industrial technologist, the environmentalist and the educator, all of whom are found amongst those who are registered for these three days of presentation and discussion. All of us should benefit.

It is my privilege to be the chairman for the Silver Anniversary Ontario Industrial Waste Conference. On behalf of the Planning Committee and the Ontario Ministry of the Environment, I wish you well in your deliberations. If any member of the Committee can assist to solve or resolve a problem, do not hesitate to approach us. We're here to make this your most successful and satisfying conference ever.

Dennis P. Caplice
Chairman

SESSION I

Chairman: J. H. Neil,
President, Limnos Ltd.,
Toronto, Ontario

Mining and the Environment — A Quarter Centry in Review
W. C. Ferguson,
Ontario Mining Association,
Toronto, Ontario

Pollution Abatement Costs — A Drop in the Bucket?
J. A. Donnan,
Senior Economist, Ontario
Ministry of the Environment

The Role of Economics in Environmental Strategies
D. N. Dewees,
Associate Professor of Economics,
Institute for Policy Analysis,
University of Toronto,
Toronto, Ontario

MINING AND THE ENVIRONMENT
- A QUARTER CENTURY IN REVIEW

BY

W. C. FERGUSON

ONTARIO MINING ASSOCIATION

IN 1977 CANADA'S MINERAL PRODUCTION AMOUNTED TO OVER 18 BILLION DOLLARS OR APPROXIMATELY 9 PERCENT OF CANADA'S GROSS NATIONAL PRODUCT. ON A PER CAPITA BASIS WE ARE THE WORLD'S LARGEST MINERAL PRODUCER. CANADA RANKS FIRST AS A PRODUCER OF ASBESTOS, NICKEL, ZINC AND NEPHELINE SYENITE AND RANKS SECOND IN THE OUTPUT OF URANIUM, SILVER, POTASH, MOLYBDENUM, SELENIUM, TITANIUM AND COLUMBRIUM. MORE THAN 60 MINERALS ARE PRODUCED FROM THE NEARLY 300 OPERATING MINES ACROSS THE COUNTRY.

THE PROVINCE OF ONTARIO IS SECOND ONLY TO THE OIL AND NATURAL GAS PRODUCING PROVINCE OF ALBERTA IN MINERAL PRODUCTION.

THE METAL MINING INDUSTRY IN ONTARIO PRODUCES MORE THAN $2 BILLION IN MINERALS EACH YEAR, OR ABOUT 40 PERCENT OF CANADA'S TOTAL METAL MINING OUTPUT. APPROXIMATELY 90 PERCENT OF THE OUTPUT OF ONTARIO'S METAL MINES IS EXPORTED AND ACCOUNTS FOR ABOUT 20 PERCENT OF THE PROVINCE'S TOTAL EXPORTS. MORE THAN 40,000 PEOPLE ARE EMPLOYED DIRECTLY IN ONTARIO MINING OPERATIONS,

AND AT LEAST FIVE TIMES THAT NUMBER ARE EMPLOYED INDIRECTLY.

ONTARIO LEADS IN THE PRODUCTION OF CADMIUM, COBALT, GOLD, NICKEL, SALT, SILVER, URANIUM AND ZINC AND IS CANADA'S SOLE PRODUCER OF CALCIUM, MAGNESIUM, NEPHELINE SYENITE, PLATINUM GROUP METALS AND YTTRIUM.

DESPITE (OR PERHAPS BECAUSE OF) ITS LARGE ROLE IN THE NATIONAL LIFE THE MINING INDUSTRY HAS OFTEN BEEN CRITICIZED FOR DESPOILING THE EARTH. CLEARLY SOME OF THE CRITICISM HAS BEEN MORE THAN JUSTIFIED. MANY OF THE SCARS ARE UGLY BECAUSE MINING IS AN ACTIVITY THAT DISPLACES THE EARTH, OFTEN ON A MASSIVE SCALE. MUCH HAS BEEN SAID IN THE NEWS MEDIA REGARDING THE IMPACT OF MINING OPERATIONS ON THE ENVIRONMENT BUT LITTLE HAS BEEN SAID OF THE SIGNIFICANT EFFORTS TAKEN BY THE INDUSTRY TO MINIMIZE THE DISTURBANCE OF THE "NATURAL ENVIRONMENT".

THE ONTARIO INDUSTRIAL WASTE CONFERENCE HAS GAINED NATIONAL RECOGNITION AS AN IMPORTANT FORUM FOR THE EXCHANGE OF TECHNOLOGY RELATED TO IMPROVING THE QUALITY OF THE ENVIRONMENT

IN WHICH WE ALL LIVE AND SHARE. IN EXAMINING THE MORE THAN 400 PAPERS THAT HAVE BEEN PRESENTED SINCE THE FIRST CONFERENCE IN 1953 ONLY 20 PAPERS OR LESS THAN 5 PERCENT HAVE RELATED TO THE MINING INDUSTRY. CLEARLY WE HAVE NOT BEEN TELLING OUR STORY. THE ONTARIO MINING ASSOCIATION WAS THEREFORE PLEASED TO ACCEPT THE INVITATION TO REVIEW THE ENVIRONMENTAL ACHIEVEMENTS IN OUR INDUSTRY AT THIS THE SILVER ANNIVERSARY MEETING OF THE ONTARIO INDUSTRIAL WASTE CONFERENCE.

THE ONTARIO MINING INDUSTRY 25 YEARS AGO

THE ONTARIO MINING INDUSTRY IN 1953 WAS DOMINATED BY THE COPPER - NICKEL OPERATIONS IN THE SUDBURY AREA AND THE THREE GOLD MINING CAMPS OF KIRKLAND LAKE, THE PORCUPINE AND RED LAKE. THE OVAL-SHAPED AREA AROUND THE CITY OF SUDBURY PRODUCED ABOUT 60 PERCENT OF ONTARIO'S MINERAL WEALTH. THE OUTPUT OF NICKEL PROVIDED 85 PERCENT OF THE FREE WORLD'S REQUIREMENTS, IT ACCOUNTED FOR HALF OF CANADA'S COPPER PRODUCTION AND THE WORLD'S LARGEST SOURCE OF PLATINUM METALS.

THE 33 ACTIVE GOLD MINES (DOWN FROM 47 A FEW YEARS EARLIER) PRODUCED 2.3 MILLION OUNCES OF GOLD PLACING ONTARIO SECOND ONLY TO THE UNION OF SOUTH AFRICA IN WORLD PRODUCTION. LARGE SCALE PRODUCTION OF IRON ORE WAS A RECENT ADDITION TO THE ONTARIO ECONOMY WITH OPERATIONS LIMITED TO STEEP ROCK IRON MINES NEAR ATIKOKAN AND ALGOMA STEEL'S HELEN MINE. PRODUCTION EXCEEDED ONE MILLION TONS.

THE COBALT MINING CAMP SHIPPED 3 MILLION OUNCES OF SILVER AND ABOUT 1-1/2 MILLION OUNCES OF COBALT.

OTHER MINING OPERATIONS INCLUDED AN ASBESTOS MINE AT MATHESON, PORTLAND CEMENT PLANTS AT BELLEVILLE, PORT COLBORNE AND ST. MARY'S, A NEPHELINE SYENITE (USED IN THE CERAMICS INDUSTRY) MINE NEAR NEPHTON AND GYPSUM PRODUCTION AT CALEDONIA AND HAGERSVILLE.

DURING 1953 THERE WERE MORE PROSPECTORS THAN EVER SEEKING MINERAL DEPOSITS IN ONTARIO. ALMOST 30,000 MINING CLAIMS WERE RECORDED - A RECORD. THE NEXT YEAR MORE THAN

50,000 CLAIMS WERE RECORDED. THE STAKED AREAS COVERED ABOUT 3,100 SQUARE MILES - MORE THAN THE AREA OF OUR SMALLEST PROVINCE, PRINCE EDWARD ISLAND! THIS FEVER PACE REFLECTED NEWS OF MASSIVE URANIUM DISCOVERIES AT BANCROFT AND BLIND RIVER AND LARGE DEPOSITS OF COPPER, LEAD AND ZINC AT MANITOUAGE LAKE. THE MINING MAP WAS SOON TO CHANGE.

THE PICTURE TODAY

SIGNIFICANT CHANGES HAVE TAKEN PLACE IN THE ONTARIO MINING INDUSTRY OVER THE PAST QUARTER CENTURY. NEW MINING CAMPS HAVE SPRUNG UP AND OLD ONES CLOSED THEIR DOORS. TODAY MAJOR BASE METAL OPERATIONS DOT THE CANADIAN SHIELD, MANY OF WORLD SCALE IMPORTANCE. MANITOUAGE, STURGEON LAKE, SHEBANDOWAN, IGNACE, CAPREOL, TEMAGAMI, RELATIVELY UNKNOWN 25 YEARS AGO ARE NOW IMPORTANT MINING CENTERS. THE TEXAS GULF ESCTALL MINE, THE WORLD'S LARGEST ZINC MINE HAS GIVEN RENEWED VIGOR TO TIMMINS, FOLLOWING THE DECLINE OF THE AREA GOLD CAMPS. URANIUM HAS TRANSFORMED ELLIOT LAKE FROM A TOURIST OUTPOST TO THE WORLD'S LARGEST

URANIUM CENTER. ASBESTOS AND IRON ORE OPERATIONS ARE NOW FOUND IN MANY CENTERS ACROSS THE PROVINCE.

MUCH OF TODAY'S MINING HAS BEEN MADE ECONOMICALLY FEASIBLE THROUGH DEVELOPMENT OF LARGE MECHANICAL MINING EQUIPMENT. HAND-HELD DRILLS ARE GIVING WAY TO JUMBO DRILLING RIGS; DIESEL AND ELECTRICALLY POWERED SCOOP-TRAMS HAVE REPLACED SLUSHERS OR MUCKING MACHINES GREATLY INCREASING PRODUCTIVITY AND MADE THE WAY FOR BULK MINING METHODS. NEW MINING METHODS INCORPORATING CEMENTED BACKFILL, ROOF BOLTING AND SCREENING PRACTICES, USE OF AMMONIUM NITRATE/FUEL OIL (ANFO) BLASTING AGENTS TO REPLACE HIGH EXPLOSIVES, ALL HAVE CONTRIBUTED TO GREATLY IMPROVED SAFETY WITHIN THE UNDERGROUND ENVIRONMENT. FEW INDUSTRIES IN THE WORLD HAVE DEVELOPED AS EFFICIENTLY AND DRAMATICALLY AS ONTARIO MINING. THE RESEARCH INNOVATION AND PROGRESS THAT HAVE MADE CANADA AND ONTARIO A LEADER IN THE HIGHLY COMPETITIVE MINING WORLD HAVE ALSO BEEN APPLIED TO THE ENVIRONMENTAL ISSUES THAT FACE MINERS EVERYWHERE.

THE ENVIRONMENTAL ISSUES

WHAT ARE THE ENVIRONMENTAL ISSUES ASSOCIATED WITH MINING? FIRST OF ALL, IT IS NECESSARY TO DEFINE MINING. IN THIS DISCUSSION MINING IS LIMITED TO THE PHYSICAL EXTRACTION OF ORES OR MINERALS FROM THE EARTH AND THE CONCENTRATION OR UP-GRADING OF THE MINED MATERIAL FOR SHIPMENT TO SMELTING OR REFINING FACILITIES LOCATED ELSEWHERE. NORMALLY ORE BODIES CONTAIN ONLY A SMALL PERCENTAGE OF METAL VALUES IN A HOST ROCK OF NO VALUE AND THEREFORE MOST MINING OPERATIONS INCLUDE A CONCENTRATOR TO REMOVE MUCH OF THIS WASTE ROCK MATERIAL. WHETHER THE MINING IS BY UNDERGROUND OR OPEN PIT METHOD, WATER COMES IN CONTACT WITH THE ORE BY RAINFALL, SEEPAGE INTO THE UNDERGROUND WORKINGS AND WATER-FLUSHED DRILLING. IN CONCENTRATION OPERATIONS LARGE VOLUMES OF WATER ARE REQUIRED TO CONDUCT THE GRINDING AND FLOTATION OPERA-TIONS AND TO HYDRAULICALLY CONVEY THE FINELY-GROUND WASTE ROCK (TAILINGS) TO A DISPOSAL SITE. IN CONTACTING THE ORES IN THESE OPERATIONS SUSPENDED OR DISSOLVED HEAVY METALS AND FLOTATION REAGENTS ARE CARRIED OFF AND CAN CONTAMINATE THE RECEIVING

WATERCOURSES IF NOT TREATED. SULFIDE ORES CAN ALSO INTRODUCE PARTIALLY OXIDIZED SULFUR COMPOUNDS THAT CAN RESULT IN LOW pH AND LOW OXYGEN CONDITIONS DOWNSTREAM. URANIUM OPERATIONS CAN ALSO FACE THE PROBLEM TO WATER-BORN RADIOACTIVE MATERIALS (RADIUM AND THORIUM).

MILL TAILINGS FORM THE LARGEST SINGLE WASTE PRODUCT FROM A MINE/MILL OPERATION. OVER THE LIFE OF A MINING OPERATION THE TAILINGS CAN REPRESENT AS MUCH AS 90 PERCENT OF THE ORE MINED AND THIS WASTE PRODUCT IN ADDITION TO BEING AN EYESORE CAN PRESENT PROBLEMS OF CONTAMINATED SEEPAGE WATER FROM PRECIPITATION LEACHING AND DUST STORMS FROM WIND EROSION. TAILINGS AREAS CAN BE IMMENSE - THE INCO MINING OPERATIONS NEAR SUDBURY HAS RESULTED IN A 2,000 ACRE TAILINGS AREA CONTAINING 400 MILLION TONS OF TAILINGS - EQUIVALENT TO THE EXCAVATION OF THE PANAMA CANAL! AT CURRENT PRODUCTION LEVELS MORE THAN 100,000 TONS OF TAILINGS MUST BE DISPOSED OF BY ONTARIO MINES EACH DAY. TOTAL TAILINGS DEPOSITED TO DATE SINCE MINING COMMENCED IN THE LAST CENTURY IS ESTIMATED TO EXCEED ONE BILLION TONS WITH A

SURFACE AREA OF ABOUT TWENTY-FIVE THOUSAND ACRES. THIS CAN BE COMPARED WITH THE 29,000 ACRES OF HIGH QUALITY AGRICULTURAL LAND CONVERTED TO URBAN USE IN METROPOLITAN TORONTO ALONE BETWEEN 1966 AND 1971.

IN THE DEVELOPMENT OF A MINE CONSIDERABLE WASTE ROCK MUST BE EXCAVATED AND DISCARDED TO GAIN ACCESS TO THE ORE BODY. IN OPEN PIT OPERATIONS DISCARD OF WASTE ROCK CAN REPRESENT VOLUMES TWO OR MORE TIMES THE VOLUME OF ACTUAL ORE BEING MINED. WASTE ROCK CAN CONTAIN MINERALIZATION AND LARGE WASTE ROCK PILES EXPOSED TO THE ELEMENTS CAN BE A SOURCE OF CONTAMINATED RUN-OFF AS SIGNIFICANT AS THE MAIN MINING EFFLUENT WATERS.

ENVIRONMENTAL SOLUTIONS

WE HAVE IDENTIFIED THE THREE PRINCIPAL EFFLUENT DISPOSAL PROBLEMS ASSOCIATED WITH MINING OPERATIONS - MINE-WATER, TAILINGS AND WASTE ROCK.

IN ONTARIO WATER QUALITY OBJECTIVES ARE ESTABLISHED BY THE MINISTRY OF THE ENVIRONMENT. CURRENT OBJECTIVES ARE SET

FOR HEAVY METAL CONCENTRATIONS, SUSPENDED SOLIDS, OILS, GREASES, PHENOLS, pH, ARSENIC, CYANIDE, COLOUR, NUTRIENTS AND TOXICITY TO FISH. SUCH "OBJECTIVES" HAVE EVOLVED IN CLOSE CO-OPERATION WITH INDUSTRY OVER THE YEARS - THE MINISTRY HAVING LONG RECOGNIZED THE NEED TO IDENTIFY ACHIEVABLE OBJECTIVES FOR OUR INDUSTRY. THE HIGH DEGREE OF EFFLUENT RECYCLE AND TREATMENT OF MINING WASTES THAT HAS BEEN ACHIEVED DURING THE PAST QUARTER CENTURY CAN BE ATTRIBUTED TO THIS CLOSE CO-OPERATION, PARTICULARLY THROUGH OUR EARLY LEARNING YEARS.

MINING OPERATIONS REQUIRE GREAT VOLUMES OF WATER BUT THROUGH RECYCLE AND TREATMENT PRACTICES DEVELOPED THE MAJORITY HAVE BEEN ABLE TO MEET THE STRINGENT WATER QUALITY OBJECTIVES SET BY THE MINISTRY OF THE ENVIRONMENT. OF THE 193 MILLION GALLONS PER DAY OF WATER USED BY ONTARIO MINES, 111 MILLION GALLONS ARE RECYCLED REDUCING THE DISCHARGE FLOW TO 82 MILLION GALLONS PER DAY. TREATMENT PROCESSES DEVELOPED HAVE REDUCED THE HEAVY METALS (PRINCIPALLY COPPER, NICKEL, LEAD AND ZINC) FOR

ALL 53 ACTIVE MINES IN THE PROVINCE TO LESS THAN 1,000 POUNDS PER DAY.

MANY NEW MINING PROCESSES ARE DESIGNED TO OPERATE ON TOTAL RECYCLE WATER AND INCORPORATE REHABILITATION OF DISTURBED LANDS IN THE ORIGINAL DESIGN. ONTARIO MINING COMPANIES HAVE LED THE WORLD IN DEVELOPING TECHNIQUES TO REVEGETATE ABANDONED TAILINGS AND WASTE PILES AND THESE EARLY SUCCESSES HAVE ATTRACTED VISITORS FROM ALL OVER THE WORLD WHO FACE SIMILAR PROBLEMS. TODAY RECYCLE AND TREATMENT OF EFFLUENT WATERS, RECLAMATION AND REVEGETATION HAS BECOME A MAJOR AND INHERENT PART OF THE ONTARIO MINING INDUSTRY.

VEGETATION OF TAILINGS IS IMPORTANT FOR SEVERAL REASONS. APART FROM DRAMATICALLY IMPROVING THE AESTHETIC ASPECTS, THE ESTABLISHMENT OF A VEGETATIVE COVER REDUCES OR ELIMINATES EROSION FROM THE TAILINGS' SURFACE AND THE OUTSIDE SLOPES OF THE IMPOUNDING DAMS. PERHAPS THE MOST IMPORTANT ASPECT HOWEVER, IS THE ROLE VEGETATION PLAYS IN REDUCING SEEPAGE OR LEACHING FROM WITHIN THE TAILINGS PILE ITSELF. RAINFALL IS INTERCEPTED AND

ABSORBED BY PLANT ROOTS AND TRANSPIRED BACK TO THE ATMOSPHERE THUS REDUCING CONTACT OF RAINFALL WITH TAILINGS.

FROM FIELD OBSERVATION IN MANY REVEGETATED SULFIDE TAILING PILES IT IS SUGGESTED THAT THE ROOT MASS, WITH ITS ATTENDANT AEROBIC BACTERIAL ACTIVITY, PROVIDE A BARRIER TO TRANSFER OXYGEN FROM THE AIR INTO THE TAILING SAND AND THUS REDUCING ACID FORMATION.

REVEGETATION OF ABANDONED TAILINGS AREAS HAS BEEN CARRIED OUT SUCCESSFULLY AT MANY MINING CENTERS. AT THE INCO SUDBURY OPERATIONS REVEGETATION TRIALS BEGAN IN THE MID 1950'S AND TODAY OVER 1,000 ACRES HAVE BEEN SUCCESSFULLY REVEGETATED. HERE GRASS WAS GROWN DIRECTLY ON THE TAILINGS SAND. IN THE PORCUPINE AREA MORE THAN 200 ACRES OF ABANDONED GOLD MINE TAILINGS HAVE BEEN REVEGETATED SINCE 1970 USING A MIXTURE OF GRASSES AND LEGUMES. MANY ABANDONED ELLIOT LAKE AREA URANIUM TAILINGS AREAS HIGH IN PYRITE AND LOW ALKALINITY HAVE BEEN SUCCESSFULLY VEGETATED OVER THE PAST FIVE YEARS.

PLANNING THE NEW MINE

LONG BEFORE PASSAGE OF THE ENVIRONMENTAL ASSESSMENT ACT, PROPOSED MINING DEVELOPMENTS HAVE INCLUDED PRE-OPERATIONAL MONITORING AND PUBLIC AWARENESS PROGRAMS. GAINING AN EARLY UNDERSTANDING OF THE LOCAL ENVIRONMENT HAS ALLOWED MORE RECENT MINING OPERATIONS TO AVOID THE PROBLEMS ENCOUNTERED BY EARLIER OPERATIONS WHERE INSUFFICIENT AWARENESS LED TO LAKE OR RIVER IMPAIRMENT, UNSTABLE OR LEAKING TAILINGS DAMS AND EXTENSIVE DESTRUCTION OF THE EXISTING SOIL AND VEGETATION CANOPY. MINE DESIGN TODAY IS SELDOM A JOB FOR A SINGLE ENGINEER; PROPER EVALUATION OF ALL THE VARIABLES REQUIRES THE INPUT OF MANY DISCIPLINES IN ORDER TO REDUCE THE IMPACT OF THE OPERATIONS TO A MINIMUM.

THE INCO LIMITED SHEBANDOWAN MINE NEAR THUNDER BAY PROVIDES A GOOD EXAMPLE OF THIS MULTI-DISCIPLINE EVALUATION APPROACH. DURING THE 1960'S SURFACE EXPLORATION PROGRAMS CONFIRMED THE EXISTENCE OF AN ORE BODY OF COMMERCIAL SIGNIFICANCE. DURING 1966-67, THE NO. 1 DEVELOPMENT SHAFT WAS COMPLETED AND UNDERGROUND EXPLORATION COMMENCED FROM THE 1,000 FT. LEVEL. IN 1968, THE DECISION

TO BRING THE MINE INTO PRODUCTION WAS ANNOUNCED. IN THE YEARS BEFORE INCO'S INTENSIVE DEVELOPMENT OF THE ORE BODY, SHEBANDOWAN LAKE HAD BUILT A WIDE REPUTATION AS A TOURIST CENTRE. OVER 750 COTTAGES ARE LOCATED ALONG ITS SHORES, AND SWIMMING, BOATING AND FISHING ARE THE SUMMER PASTIMES OF THE RESIDENTS. THE RESIDENTS EXPRESSED CONCERN OVER THE DEVELOPMENT OF A MINE IN THE MIDST OF THEIR VACATIONLAND. BASED ON CONCERN FOR ENVIRONMENTAL PROTECTION, AND TO REASSURE LOCAL CITIZENS, INCO INITIATED AN INTENSIVE ENVIRONMENTAL STUDY TO DEFINE THE ECOLOGY OF THE REGION BEFORE THE MINE OPERATIONS BEGAN. THIS WOULD HELP PREDICT ANY ADVERSE EFFECTS AND MITIGATE THEM BEFORE ENVIRONMENTAL DAMAGE COULD OCCUR.

THE ORE BODY LIES DIRECTLY BELOW THE LAKE IN SOUTHWEST BAY OF SHEBANDOWAN LAKE. THE PRINCIPAL ORE MINERALS ARE PYRRHOTITE, PENTLANDITE AND CHALCOPYRITE. IF THE PROPERTY HAD BEEN DEVELOPED ACCORDING TO SHORT-TERM ECONOMIC CRITERIA ALONE, IT IS QUITE LIKELY THAT PART OF LOWER SHEBANDOWAN LAKE WOULD HAVE BEEN DRAINED TO PERMIT MINING BY OPEN-PIT METHODS. THIS WAS NOT AN ACCEPTABLE ALTERNATIVE BECAUSE OF THE VALUE OF THE AREA AS

RECREATION LAND AND AS WILDERNESS. THE AQUATIC ENVIRONMENT WAS RECOGNIZED AS BEING OF GREATEST CONCERN. THE MAJORITY OF THE PROGRAMS WHICH WERE LATER INITIATED WERE DIRECTED TOWARDS PROTECTION OF THE WATER. THE RIVER SYSTEMS OF THE AREA ARE SENSITIVE, WITH LOW NUTRIENT STATUS AND WITH LITTLE BUFFERING ABILITY. THIS MEANS THAT UNCONTROLLED INTERFERENCE WITH THE EXISTING AQUATIC ENVIRONMENT COULD HAVE WIDE-RANGING CONSEQUENCES AND THAT THE RECOVERY FROM SUCH AN INTERFERENCE WOULD, AT BEST, BE SLOW. AN EXTENSIVE WATER QUALITY MONITORING PROGRAM HAD TO BE UNDERTAKEN WELL AHEAD OF PRODUCTION.

THE OBJECTIVES OF THE MONITORING PROGRAM WERE TO DETERMINE THE CHARACTERISTICS OF THE AQUATIC ENVIRONMENT IN THE VICINITY OF THE MINING OPERATIONS AND, PARTICULARLY IN THE INITIAL STAGES, TO DETERMINE THE BASELINE CONDITIONS BEFORE THE MINE CAME INTO PRODUCTION. CLOSE EXAMINATION OF TOPOGRAPHIC MAPING OF THE AREA SURROUNDING THE MINE SITE WITHIN A RADIUS OF SEVERAL MILES REVEALED ONLY TWO SEPARATE RECEIVING WATERCOURSES ; THE GOLD-CREEK-MATAWIN RIVER SYSTEM AND LOWER SHEBANDOWAN LAKE.

THE PRE-OPERATIONAL WATER QUALITY MONITORING PROGRAM CONCENTRATED ON THE EXAMINATION OF THESE TWO POTENTIAL RECEIVING WATERCOURSES IN ORDER TO EVALUATE THEIR ABILITY TO ASSIMILATE THE EVENTUAL WASTE WATERS FROM THE MINE/MILL UNDER DEVELOPMENT. RESULTS OF A TWO YEAR MONITORING PROGRAM REVEALED PHYSICAL AND CHEMICAL CHARACTERISTICS TYPICAL OF MOST OLIGOTROPHIC NORTHERN WATERS. THE WATERS ARE SOFT WITH VERY LITTLE BUFFERING CAPACITY AND LOW CONCENTRATIONS OF PLANT NUTRIENTS. THE BIOLOGICAL COMMUNITIES ALSO REFLECT THIS - BOTH PHYTOPLANKTON AND BENTHIC ORGANISM COUNTS WERE LOW.

EXAMINATION OF THE AREA FOR SUITABLE TAILINGS DISPOSAL SITES REVEALED ONLY ONE IDEAL SITE - BY DEFINITION OF AN IDEAL SITE AT THIS PROPERTY - A SITE THAT COULD BE DEVELOPED WITH MINIMUM DAM CONSTRUCTION, LOW PERMEABILITY OF THE UNDERLYING SOIL AND CAPABLE OF STORING THE ENTIRE TAILINGS DISCHARGE OVER THE EXPECTED 15 - 20 YEAR LIFE OF THE OPERATION. SUCH A SITE WAS IDENTIFIED SOME 10,000 FEET DUE EAST OF THE MILL SITE AND LOCATED IN A 300

ACRE BASIN FORMING THE HEADWATERS OF GOLD CREEK. IT WAS ANTICIPATED THAT THE DISCHARGE OF HIGH-SULFATE TAILINGS EFFLUENT INTO GOLD CREEK WOULD CHANGE THE EXISTING SOFT WATER ENVIRONMENT INTO A MODERATELY HARD WATER ENVIRONMENT IN AT LEAST THE UPPER REACHES OF THE CREEK.

CONCURRENT WITH PRE-OPERATIONAL MONITORING, PILOT PLANT WORK ON SHEBANDOWAN ORE SAMPLES SHIPPED TO COPPER CLIFF REVEALED THAT MILL RECOVERY EFFICIENCY COULD BE MAINTAINED WHEN OPERATING IN CLOSED-CIRCUIT WITH THE TAILINGS POND. THE STUDIES ALSO INDICATED THAT DUE TO THE ULTRA-BASIC HOST ROCK ACID GENERATING POTENTIAL OF THE TAILINGS WAS LOW AND LOW pH/HIGH SULFATE LEVELS SHOULD NOT BE EXPECTED.

BASED ON THE RESULTS OF A MULTI-DISCIPLINE STUDY PROGRAM OF PROCESSING STUDIES; HYDROLOGIC AND METEOROLOGICAL INVESTIGATION, BIOLOGISTS AND SOILS SCIENTISTS, THE FOLLOWING MINING AND MILLING OPERATION WAS DEVELOPED.

1. THE ORE UNDERLYING LAKE SHEBANDOWAN IS HOISTED UP NO. 2 SHAFT THEN CONVEYED ONE HALF MILE BACK FROM THE LAKESHORE TO REMOVE THE CONCENTRATOR OUT OF SITE FROM THE LAKE.

2. UNDERGROUND MINE WATER INCLUDING IN-LEAKAGE FROM THE LAKE IS PUMPED TO SURFACE AND ON TO THE TAILINGS DISPOSAL AREA. AS THE CONCENTRATION OPERATION IS IN CLOSED-CIRCUIT WITH THE TAILINGS AREA, THE MINE WATER AND THE RELATIVELY SMALL FLOW OF SANITARY WASTES ARE THE ONLY WATERS REPORTING IN OPEN CIRCUIT TO THE TAILINGS POND.

3. TO IMPROVE MINE WATER QUALITY A WATER TREATMENT PLANT IS LOCATED BELOW THE 2,000 FOOT LEVEL AT #2 SHAFT TO REMOVE ALL SETTLEABLE SOLIDS PRIOR TO DISCHARGE TO THE TAILINGS AREA. THE TREATMENT FLOWSHEET CONSISTS OF A 100' LONG X 16' WIDE CLARIFIER WITH THE COLLECTED SLUDGE REPORTING TO A VACUUM FILTER STATION DISCHARGING FILTER CAKE ONTO AN ORE CON-

VEYOR. DETAILS OF THE INCO-DEVELOPED UNDERGROUND CLARIFICATION/FILTRATION SYSTEM HAVE BEEN DESCRIBED ELSEWHERE.

4. THE 300 ACRE TAILINGS POND WAS DESIGNED TO BE SUFFICIENT FOR THE EXPECTED LIFE OF THE OPERATION. THE COARSE TAILINGS ARE USED AS BACKFILL UNDERGROUND. ONLY THE FINE TAILINGS ARE DISCHARGED IN THE DISPOSAL AREA FOR SEDIMENTATION AND RECYCLE.

ONE MAJOR DRAWBACK TO THE SETTLEMENT OF FINE TAILINGS IN TAILINGS PONDS IS WAVE ACTION CREATED BY EVEN LIGHT WINDS. THE SHEBANDOWAN TAILINGS POND WAS ORIGINALLY A PEAT FILLED DEPRESSION WITH A COVER OF PINE AND SPRUCE. THE TREES WERE LEFT TO STAND INSIDE THE IMPOUNDMENT DAMS. THE TREES REDUCE WAVE ACTION AND ASSIST IN SUSPENDED SOLIDS REMOVAL. SUSPENDED SOLIDS IN THE OVERFLOW OR RECYCLE SYSTEM HAS NORMALLY BEEN BETWEEN 1 AND 5 PPM.

THE MONITORING PROGRAM INITIATED IN THE PRE-OPERATIONAL PHASE HAS CONTINUED FOLLOWING START-UP OF OPERATIONS IN 1973.

NO SIGNIFICANT CHANGE IN THE PHYSICAL, CHEMICAL OR BIOLOGICAL PARAMETERS HAVE BEEN DETECTED TO DATE. THE MINE APPEARS TO HAVE HAD A NEGLIGIBLE EFFECT ON THE ECOLOGY OF THE RECEIVING WATER-COURSE.

SUMMARY

MINING OPERATIONS CAN AND HAVE DISTURBED THE NATURAL ENVIRONMENT. PROPER PLANNING, HOWEVER, CAN PRODUCE A MINING PLAN THAT WILL ALLOW MINING OPERATIONS TO BE CARRIED OUT IN HARMONY WITH THE UNDISTURBED SURROUNDINGS. TODAY RECYCLE AND TREATMENT OF EFFLUENT WATERS, RECLAMATION AND REVEGETATION HAS BECOME A MAJOR AND INHERENT PART OF THE ONTARIO MINING INDUSTRY.

POLLUTION ABATEMENT COSTS

A DROP IN THE BUCKET?

by
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A number of adverse economic circumstances are reportedly threatening the competitive position of Canadian business and manufacturing enterprises. Spokesmen for various industrial sectors in Canada and Ontario have been especially vocal in their assertions that Canadian operations are often more costly than their competitors in the United States.[1] Industry is particularly concerned that the costs of meeting pollution abatement objectives in Ontario could threaten the financial integrity of some industrial operations. We are warned that some hard trade-off decisions will have to be made, especially with respect to jobs and the environment.[2]

I would expect that most of you here will agree that air and water pollution cause damages to people and property and I doubt that any of you would advocate the complete elimination of environmental regulations. But there is disagreement as to how much and how fast pollution abatement should be implemented. This disagreement arises primarily from the fact that significant extra costs may have to be incurred to undertake environmental controls.

This morning, I would like to give an economic perspective and structure to this debate. In doing so, I shall discuss some of the more interesting issues associated with the costs of pollution abatement, including:

1. environmental objectives and the severity of Ontario's environmental laws and requirements as opposed to those in other jurisdictions;

2. the effect on the competitiveness of Ontario and Canadian industry;

3. the magnitude of past and future pollution abatement expenditures;

4. factors which mitigate the costs of abatement;

5. jobs and the environment; and,

6. can industry "afford" pollution abatement?

Finally, I shall suggest how environmental-economic trade-offs can be made in a more explicit, rational and equitable manner.

A RATIONALE FOR GOVERNMENT ACTION

No-one ever sets out to willfully poison the air or water. However, all human activities generate wastes or by-products which must be eliminated in some manner. Traditionally, individuals, manufacturing plants, businesses and even governments have disposed of their wastes as cheaply as possible by discharging them into the three great waste sinks: the water, the atmosphere or the land.

Each of these elements of the environment are valuable natural assets although land differs fundamentally from the atmosphere and natural waterbodies in that it can be privately-owned. However, no-one, not even governments, can

easily hold a clear title of ownership to the air, rivers, the Great Lakes or the oceans primarily because of the indivisibility of these resources.[3] Consequently, individuals, corporations and governments have been able to use a nearby river, lake or the atmosphere to dispose of waste products at no cost. Thus, all of us have an economic incentive to discharge wastes directly into rivers, lakes and the atmosphere free of charge instead of incurring costs to recover, recycle, treat or otherwise reduce these waste emissions.

Waste disposal per se does not constitute a pollution problem since both the atmosphere and water bodies have a certain capacity to assimilate and disperse waste products. Pollution problems result when waste discharges exceed this capacity so that people, property or activities are adversely affected by waste emissions or their residues.

When pollution damages do occur, the sectors of the population or the activities that are affected are generally unconnected or external to the polluter. Consequently, the use of a river by a factory to dispose of its wastes appears costless to the mill, even though values for other uses of the river are degraded or destroyed. Polluting industries can be said to be receiving an "environmental subsidy" by using the atmosphere and surface waters as a waste sink free of charge. Companies must pay for virtually all of their raw materials, labour and other goods that they use in their activities but they do not pay anyone rent or a fee to use the environment to dispose of wastes. Polluters, and that

means individuals and governments as well as manufacturers, reap the benefits of abatement costs which they avoid while other people, and society in general, incur the costs and risks of pollution damages.

Manufacturing establishments throughout Canada and the U.S. have long utilized nearby watercourses and the atmosphere as their primary waste disposal systems. Why then, are individuals and environmental control agencies so concerned about such pollution now, after decades of tacit and sometimes overt, approval by governments in the name of employment and economic development?[4]

First, as industrial output has expanded, the quantities of pollutants have increased as well. Consequently, materials that were once assimilated by natural processes in a harmless manner are now concentrated to the extent that they can be injurious. Second, growth in population and industrial production have brought people and pollutants closer together and so have increased both the frequency and the intensity of pollution damages. Thirdly, public awareness and expectations concerning environmental quality have been raised considerably. People in the cities of Southern Canada express a preference for clean streams in the North even though they are unlikely ever to visit them. Fourth, technical progress has enabled scientists to detect heretofore unknown toxic and hazardous elements in wastewaters and in receiving rivers and lakes (i.e. mercury). Moreover, scientists have traced the biological pathways of some of

these dangerous substances through natural food chains to human beings.

Finally, there is no institutional mechanism in the market economy for those sectors of society who want clean air and water (i.e. conservation groups, hunters and fishermen, etc.) to induce polluters to change their behaviour. Indeed, the costs of pollution are imposed on parties who do not normally benefit directly from a polluter's activities and are usually not compensated by waste dischargers.

Economic research and experience has shown us that waste dischargers generally respond only to private costs they must incur to do business and to the private benefits or revenues that they receive for their products or services. Public or external costs and damages caused by pollution are normally not included in the economic calculations of individuals or corporations. To the extent that pollution damages are not borne by polluters, waste generators find it cheaper to continue polluting rather than install pollution abatement.

Provincial and Federal governments are the only elements of society with sufficient wealth, power and jurisdictional authority to undertake the research, the monitoring and the enforcement necessary to deal with pollution problems. Governments have, therefore, enacted legislation, established objectives and have undertaken

collective action to curtail pollution and resolve environmental conflicts where they exist.

ENVIRONMENTAL DAMAGES AND COSTS

The waterborne and airborne waste products of industry and of people in general can cause a variety of effects and damages. If waterborne wastes contain heavy metals or other toxic chemicals, they can pose a threat to human health. Materials that settle out of receiving waters make rivers and lakes inhospitable to aquatic life and to recreational uses. A multitude of chemicals and oxygen-demanding organic materials found in industrial wastewaters can kill fish outright, give their flesh an offensive flavour and can further make the aquatic environment inhospitable to fish and other aquatic organisms. The colour, the foaming and the smells resulting from decomposition in the water are aesthetically offensive.

Airborne particulate matter can soil buildings and clothing while sulphur dioxide can cause physical discomfort, damages to structures and automobiles and perhaps even increases in the incidence of certain diseases over a long period of time.

In a few instances where wastewaters or the gaseous emissions from industrial establishments have clearly caused damages to downstream water users or nearby homeowners, these victims have sought and obtained some compensation

through the courts. If the external costs of pollution were limited to only a few, identifiable victims, then compensation arrangements could be worked out between the polluter and the victims. Indeed, individuals in some communities may be willing to endure a certain degree of discomfort in exchange for employment and economic security, although I have seen no real documentation to support this contention. Nevertheless, if these circumstances prevailed, little government intervention would be required.

However, many of the damages caused by industrial and municipal effluents are imposed on unowned, natural environmental resources. In addition, many of the damages and the victims are so widely dispersed that the costs of seeking out and compensating all victims are prohibitive and, of course, polluters have no real incentive to do this. Finally, there is the problem of undertaking research to determine whether there are future damages, which no-one as yet knows about, that could be caused by wastewater effluents or air emissions. Again, the private market economy provides no financial incentives to carry out this function.

It is, therefore, necessary for Provincial and Federal governments to intervene in order to formulate and enforce laws and policies intended to protect common property resources like the air and water from overuse, misuse, and despoilation. Because the market economy does not ration and efficiently allocate the use of these common property resources, this task falls to the government by default.

ENVIRONMENTAL OBJECTIVES

The environmental objectives promulgated by various government agencies have been the subject of some confusion. In addition, there have been both hints and assertions that Ontario's pollution abatement "requirements" are tougher than those of other jurisdictions, particularly Quebec and the United States[5]. Typically, those who have made these assertions offer no real evidence to support their contentions.

Our own systematic investigations have indicated that Ontario's pollution abatement "requirements" are not any more burdensome than those that are evolving in other jurisdictions. There are a number of reasons that lead to this conclusion. In the first place, every Provincial and State government as well as the U.S. and Canadian Federal Governments have enacted environmental laws. One basic difference between the U.S. Federal and Canadian legislation is that the U.S. Water Pollution Control Act and Amendments specify explicit target levels of abatement and timetables for compliance[6]. Likewise, deadlines for complying with vehicle emission standards have been included in the U.S. Clean Air Act. In contrast, Canadian legislation, including the Ontario Environmental Protection and Water Resources Acts and the Federal Fisheries Act; all contain general prohibitions against the discharge of contaminants. The setting of ambient quality standards of allowable effluent

loadings and timetables for compliance are left to the discretion of the relevant abatement agencies[7].

Standards, regulations, criteria, guidelines and requirements are all terms that are used and misused to refer to environmental objectives and one must be clear as to meaning in order to compare them in different jurisdictions. Standards are specific, quantitative limits to allowable contaminant levels that are codified in a Regulation under the authority of a specific Act. Standards indicate the maximum allowable contaminant level in the ambient air or water. Ambient refers to the quality of water in the lake or river or the quality of the air we breath. Standards may be used to specify the allowable quantity of a contaminant in a waste discharge. Regulations are rules that are issued in exercise of a legislative power under the authority of a statute. A Regulation may specify the use of a cleaner burning fuel or prohibit the use of a certain chemical. Criteria are objective, quantitative allowable levels of contaminants determined by research but are not codified in a statute or a regulation. A guideline is a recommended good practice.

Three agencies have established environmental objectives that are relevant to Ontario. The International Joint Commission has published ambient water quality objectives for the Great Lakes (International Joint Commission, September 1976).

State, provincial and federal environmental enforcement agencies use these objectives in setting their own standards and guidelines. This has promoted uniformity of objectives among the Great Lakes jurisdictions. Secondly, the Canadian Federal Department of the Environment has promulgated regulations as to the allowable contaminant loadings in wastewaters for specific industrial sectors under the authority of the Canada Fisheries Act. Air emission standards have not been established under the Canadian Clean Air Act although National Air Quality Objectives have been published. Finally, the Ontario Ministry of the Environment is empowered to establish regulations under The Environmental Protection Act, The Ontario Water Resources Act, The Pesticides Act and The Environmental Assessment Act. Point-of-impingement ambient air quality standards have been specified in Regulations issued under The Environmental Protection Act. It is from these standards that allowable emission levels from specific sources are determined.

On the other hand, no Regulations or standards have yet been established by the Ministry of the Environment for ambient water quality or wastewater loadings. Instead, effluent guidelines have been developed for each major industrial plant, based primarily on the characteristics of receiving waterbodies. The implied costs of abatement are lower than they would be if a single set of standards were applied throughout the province. The use of guidelines instead of Regulations was also consistent with the Ministry's

long standing efforts to obtain voluntary compliance from industry.

It is the stated policy of the Federal Government to require a minimum degree of waste treatment across the nation so as to prevent the establishment of "pollution havens" in areas hungry for industrial development. Where federal regulations apply, they are intended to take precedence over Provincial standards except when the Provincial standards are more stringent.

How do we arrive at the standards, criteria, guidelines or other objectives that you must all translate into pollution control projects? To some, the objectives may seem overly stringent and, in some cases, rather arbitrary. However, our Ministry's mandate is to protect the integrity of ecosystems and their component parts as well as human health. It must be remembered that these natural systems (forests, lakes, rivers, oceans, the soil, etc.) provide the life support mechanisms for all of us and in many instances, these receptors are far more sensitive to some pollutants than are humans. Therefore, the allowable ambient quality or effluent loading levels that are intended to protect fish and vegetation are often far below those levels that affect humans.

There is often, however, uncertainty concerning these effects and they may vary over a wide range of contaminant levels. In many situations, there is no real threshold

level; only a gradual diminuation of effects down to zero discharge. In these cases, we need an objective rule or criterion to make a decision as to how much abatement should be implemented. Economists can provide such an objective rule in the concept of efficiency.

In order that society may obtain the best use and enjoyment from all of its resources, private as well as public, it should reduce pollution in the most efficient manner possible. Pollution abatement will be accomplished most efficiently when the extra costs of abatement are just equal to the additional benefits (or reduction in pollution damages) gained. If one installs more pollution abatement than this, more resources will be spent on abatement than would be justified by the benefits gained. If abatement is cut back from this point, the social damages incurred will likely be greater than the abatement costs saved. This level of pollution (or abatement) is considered to be socially optimal in two respects. First, it is the level at which the costs of abatement are commensurate with the private and public benefits (damages avoided or reduced) of abatement. Secondly, social welfare will be diminished if abatement were increased (society spends more resources on pollution abatement than it need to), or decreased (social and environmental damages would be greater than the costs of abatement) beyond that point.

The practical application of this principle is limited by the availability of data and the problem of timing. While

the costs of abatement often have to be incurred in the present, the benefits may take years to materialize. Consequently, both the short and the long-run benefits and costs of abatement must be identified and empirically adjusted by discounting procedures. Most importantly, the principle described above implies that we need to know explicitly the costs and the benefits of several different levels of abatement, not just the single-valued abatement cost estimates that are occasionally published in the media.

In addition to the problem of inducing existing polluters to clean up, Certificates of Approval from the Ministry are required in Ontario of anyone who intends to build new or expanded facilities that generate or process wastes. The review process and the guidelines that go along with Certificates are intended to prevent pollution damages that would impose costs on society. Firms that install pollution abatement also avoid costly retrofitting of abatement equipment in the future.

While there may be a degree of consistency among the laws and environmental objectives found in different jurisdictions, enforcement activities can vary considerably. Although we have not made a systematic comparison of enforcement activities among different jurisdictions, we have noticed that there has been much more litigation and far higher fines or financial penalties resulting from prosecutions in the U.S. than in Ontario. Ontario is certainly no more zealous in its enforcement than the U.S.

A major concern of industry is that environmental objectives or regulations might be changed in the future and that such targets as zero discharge might become government policy. The record shows that environmental objectives have been introduced or changed rather infrequently and seldom without justification. Moreover, I personally find it unreasonable for industrialists who live with fluctuations in sales and in the prices of raw materials to expect complete stablility with respect to pollution Regulations and guidelines. No one can guarantee that new knowledge or some new crisis will not result in the need to change environmental objectives or abatement processes.

FACTORS WHICH MITIGATE THE COST OF POLLUTION ABATEMENT

In our 1974 report on the pulp and paper industry, Peter Victor and I identify two complementary types of environmental policy instruments.

1. Implementation incentives that give polluters an incentive to undertake abatement programs including negotiations, control orders, prosecutions and fines;

2. Financial assistance policies that mitigate the financial impact of pollution abatement costs.

Instruments of this second type are often misnamed incentives. Unless assistance programs pay for all of the costs of abatement, polluters continue to face additional control costs and so have an economic incentive to put off these projects.

Media reports invariably cite the full market prices of pollution abatement systems when referring to the financial impact of such costs on industry. There are, however, several factors which reduce, to some extent, the actual costs that are borne by the polluting firm.

Timing is a key factor. Phasing-in abatement expenditures over several years will substantially lower the impact of costs on the firm. Moreover, the equipment will normally last 10 to 20 years with the costs being amortized over this period of time.

The corporate tax system also acts to distribute the costs of abatement between industrial tax-payers and the government. Because private businesses must pay about half of their profits (36% Federal and 12% Ontario) to the government as taxes, the actual reduction in after-tax profits for any single year will be approximately ½ of the capital costs incurred plus ½ of the annual operation and maintenance expenses. The government thus bears part of these abatement costs in the form of reduced tax revenues.

The Accelerated Capital Cost Allowance Program (ACCA) softens the impact on profits even further. As a result of this provision, the actual reduction in after-tax profits in a given tax year is about one-fourth of the market price of the equipment. Finally, pollution abatement equipment is exempt from both Federal and Provincial sales taxes.

Pollution abatement is generally assumed to impose costs with little or no return on investment. While this may be true in many instances, there are often opportunities to recover part of the abatement costs through reduced input requirements, by-product recovery or increased product efficiency. I don't know exactly how much research and development is going on to find new and better ways of accomplishing pollution reductions, but I do know that financial incentives to undertake this research and development are infinitely smaller than the incentives to delay or avoid incurring the costs of pollution abatement.

The tax concession measures that are available are not altogether satisfactory to firms or to the public. For one thing, not all of the capital expenditures may be eligible for the ACCA. For example, buildings that house pollution abatement equipment, smokestacks and dams and levees for mine tailings disposal may not be eligible for the ACCA. In addition, the ACCA or the sales tax exemptions are not clearly apparent (to the public) forms of assistance. The amounts of assistance implied by these programs are often lost in the complexities of corporate income tax computations. Finally, these tax measures do not cushion the impact of large cash outlays or debts for the purchase of abatement systems. Other forms of financial assistance to industry are being studied but the kinds of assistance programs that we have in place today are consistent with the "polluter-pays" principle which is endorsed by both Federal and Provincial governments.

THE COSTS OF POLLUTION ABATEMENT

Pollution abatement costs have a number of important and somewhat unique characteristics. In the first place, the cost of reducing any type of pollution tends to increase more than proportionately with the amount of pollution removed. The greater the degree of abatement, the greater the cost per unit of pollutant removed. In economic jargon, pollution abatement, particularly at high levels, is subject to increasing marginal costs.

Secondly, the costs of pollution control vary substantially from source to source, industry to industry, firm to firm, place to place. To keep costs to a minimum, the extent to which individual sources must reduce their discharges should vary in relation to the costs of abatement. Abatement should therefore proceed first in those facilities where costs per unit of waste reduction are the lowest. Some authorities state that, in order to be equitable, a common level of pollution abatement should be achieved by all polluters. For example, an amendment to the U.S. Water Pollution Control Act requires that all industries install the "best available technology" by a specific deadline. However, because both the costs of abatement and pollution damages vary widely from plant to plant, such an approach will be inequitable in that some firms will have to pay much more than others to reach the same level of treatment technology.

Third, for almost every type of pollution problem, there exists a large number of alternative control measures. Our research has shown that permutations and combinations of only five or six different wastewater treatment technologies in a single industrial plant can yield hundreds of possible abatement programs. (Donnan & Victor, 1974, Vol. I, Appendix G). In one pulp and paper mill studied, 206 different abatement programs were found to be technically feasible under a given set of constraints. A steel mill we are reviewing has thousands of combinations of treatment options. Each of these alternative programs had a different set of costs and waste discharge levels.

We have developed an automated system that allows us to explicitly identify all of the technically feasible programs, to assess the capital and O and M costs of each and to determine the resulting waste loadings. From these data, a schedule of least-cost programs to achieve successively lower levels of pollution loadings can be prepared. We call this schedule an Abatement Cost Function. An Abatement Cost Function is an essential element of any procedure to make environmental-economic trade-offs.

How much has actually been spent on pollution abatement facilities in Canada and Ontario? This information is of interest for three reasons:

1. the data give an indication of the relative activity in this area by different sectors;

2. by comparing these pollution abatement expenditures figures with other economic parameters, we can determine the relative burden of pollution abatement costs on different sectors of the economy;

3. we can get an idea of trends; i.e., are different sectors increasing or decreasing their commitment to pollution abatement?

The amount of money spent is, of course, not a measure of pollution abatement accomplishments. The relevant measure of the pollution abatement performance of a municipality, an industry or a specific company is the reduction in waste loadings and environmental damages.

First, let us look at public expenditures. Table 1 contains a list of the total value of both new and repair construction for waterworks and sewage systems in Ontario and Canada for the years 1972 and 1975. These data are contrasted with total construction in these two jurisdictions. Table 2 includes the expenditures made by Provincial Governments on various environmental functions as compared with their respective total budgets. It does not appear that direct government expenditures for environmental functions claim an excessive proportion of these resources. Moreover, the Ontario Ministry of the Environment employs only 2.6% of the total staff of our Provincial Government.

TABLE 1

Total Value of Construction (New and Repair) of Waterworks and Sewage Systems, Canada and Ontario

($000,000)[1]

Year	ONTARIO			CANADA		
	Water and Sewage	Total Construction	%	Water and Sewage	Total Construction	%
1972	291.8	6,275.8	4.6	714.3	17,288.9	4.1
1973	319.1	7,136.0	4.5	791.1	20,173.8	3.9
1974	456.1	8,501.3	5.4	1,078.5	24,693.1	4.4
1975	518.7	8,989.4	5.8	1,241.3	28,376.3	4.4
1976[2]	533.9	9,831.2	5.4	1,315.8	31,773.2	4.1

[1] Values given in nominal dollars (i.e. not adjusted for inflation).

[2] 1976 figures are preliminary.

Source: Statistics Canada, Construction in Canada, Catalogue No. 64-201.

TABLE 2

Expenditures on Environmental Functions by Canadian and Provincial Governments, 1975-76

Jurisdiction	Agency	Expenditure on Environmental Functions	Provincial Government Budget Including Disbursements	Total Environment Expenditures as a % of Government Budget
		(millions of dollars)		
Canada	Environment Canada	204		
	Urban Affairs-CMHC forgiveable loans	44		
Ontario	Ministry of the Environment			
	- Services	68.2		
	- Disbursements & Grants	170.0		
	TOTAL	238.2	12,039.0	1.98
British Columbia	Lands, Forests & Water resources			
	- water resources	25		
	- environment & land use committee	2.1		
	TOTAL	27.1	3,377.0	.80
Alberta	Environment			
	- services	22.3		
	- capital account	40.4		
	TOTAL	62.7	6,138.0	1.02
Manitoba	Mines, Resources & Environmental Management			
	- environment	4.2		
	- water management	8.5		
	TOTAL	12.7	1,831.0	.69
Saskatchewan	Dept. of Environment	4.5	1,170.7	.38

.... cont'd

TABLE 2 (cont'd)

Comparative Expenditures on Environmental Functions by Canadian and Provincial Governments

(1975-76)

Jurisdiction	Agency	Expenditure on Environment	Provincial Government Budget Including Disbursements	Total Environment Expenditures as a % of Government Budget
		(millions of dollars)		
Quebec (1974-75)	Natural Resources			
	- water sector	9.4		
	Municipal Affairs			
	- enviromental health	3.1		
	- assistance for water projects			
	. w & s works	18.7		
	. water mgt.	13.4		
	. other	1.4		
	TOTAL	46.0	7,184.0	.64
New Brunswick	Environment	2.8	866.0	.32
Nova Scotia	Environment	5.5	949.0	.57
P.E.I.	Environment	3.05	180.0	1.69
Newfoundland	Provincial Affairs and Environment	.801	708.0	.11

Source: Public Accounts of each Province.

Expenditures by industry on pollution abatement are more difficult to document. We have identified several sources of such data, each of which has some limitations.

Statistics Canada does not collect or publish statistics on pollution abatement expenditures by industry. Statistics Canada does, however, publish the amounts claimed for pollution abatement (Classes 24 and 27) each year under the Accelerated Capital Cost Allowance Program (ACCA). One can calculate the implied abatement expenditures for all of Canada on the basis of these data. In addition, Environment Canada maintains records of the running total dollar value of claims made under the ACCA program and provides these data aggregated by province. These data tend to understate pollution abatement expenditures because companies may not claim all they are entitled to under the ACCA program and because some costs are not eligible for ACCA. For example, the construction of smoke stacks has not been eligible for the ACCA.

Some industrial associations collect data on expenditures with the most systematic and comprehensive being the Canadian Pulp and Paper Association. Figures that we have been able to obtain from other associations were incomplete and were not systematically collected.

Table 3 indicates the amount spent for pollution abatement by specific industrial aggregations as calculated

TABLE 3

ESTIMATES OF EXPENDITURES FOR POLLUTION ABATEMENT
BASED ON THE ACCELERATED CAPITAL COST ALLOWANCE - CANADA

Sector	Total Expenditure Air & Water Pollution 1966-1975 ($ 000,000)	Total Capital Investment (New Plant & Equipment) 1966-1975 ($ 000,000)	Pollution Abatement Expenditures as a Percentage of Total Investment
Mining	$ 77.8	$15,390.1	.51
All Manufacturing	632.6	33,551.3	1.89
Primary Metals	150.2	4,314.4	3.48
Petroleum & Coal	85.0	2,327.7	3.65
Chemicals & Chemical Products	78.2	3,638.1	2.15
Pulp & Paper & Allied Industries	192.2	4,736.3	4.06
CPPA (1972-1976) Data	340.1	2,670.7	12.7

Sources: Accelerated Capital Cost Allowances - Statistics Canada, Corporation Taxation Statistics; #61-208.

Total Investment - Statistics Canada, Private and Public Investments, Annual Outlook; #61-205.

CPPA. Personal communication with the Canadian Pulp and Paper Association, Montreal.

on the basis of ACCA data. Implied expenditures over a 10-year period are compared with the total investment in new plant and equipment for the period as reported by Statistics Canada.

I mentioned that these ACCA figures do not capture all of the actual expenditures. Consequently, expenditures that are reported to the Canadian Pulp and Paper Association for the year 1972-1976 are shown in Table 3 for comparison. Where the ACCA figures indicate that the pulp and paper industry spent about 4% of their new capital investment on pollution abatement, the figures reported by the CPPA amount to about 13% of the industry's new capital expenditures for that period. Another reason for these differences is that some expenditures were reported as pollution abatement equipment to the CPPA which are considered to be production equipment by government analysts although an effort is made by CPPA statisicians to apportion costs between abatement and productivity. Some kinds of equipment contribute to increased productivity as well as to decreased pollution emissions. Firms have an incentive to attribute all of the costs of such equipment to pollution abatement to take advantage of tax concessions such as the ACCA Program and to indicate that they have been active in pollution abatement. Firms also claim that all of the costs of a productivity improvement should be allocated to environmental purposes if they install such equipment only because they are required to do so by an abatement agency.

There are three other sources of industrial pollution abatement expenditure data in Ontario.

The Ontario Pollution Abatement Incentive Act provided a grant system that amounted to a rebate of the Provincial Sales Tax on eligible expenditures. The Act was repealed in April 1977 so that we only have data for the years 1970 to 1977 from this source. These figures may also understate total expenditures because some firms did not apply or some expenditures were ineligible.

Estimates of costs are also included in the applications for industrial Certificates of Approval from the Ontario Ministry of the Environment. These figures are, however, only estimates and may be higher or lower than the actual expenditures. Moreover, the expenditure may actually be incurred several years after the application is submitted. Finally, until 1977, cost estimates for air pollution control projects were not requested on the application forms hence the figures for previous years related only to water pollution control projects.

A third source is the rather informal compilation of individual company data by staff in our Ministry who have day to day contacts with different industries. We do not have systematic data concerning the extra operating and maintenance costs that have been imposed by pollution abatement programs.

TABLE 4

DISBURSEMENTS OF GRANTS UNDER THE ONTARIO POLLUTION ABATEMENT INCENTIVES ACT AND IMPLIED CAPITAL EXPENDITURES FOR POLLUTION ABATEMENT

Fiscal Year (1 April-31 March)	Total Claims Paid	Retail Sales (%)	Implied Expenditures
1970/71	$ 413,881	5	$ 8,277,620
1971/72	1,884,889	5	38,897,780
1972/73	2,307,076	5	46,141,520
1973/74	1,571,963	7	22,456,614
1974/75	2,749,389	7	39,276,986
1975/76	3,242,125	7	46,316,071
1976/77*	6,175,339	7	88,219,129
Totals	18,404,662		289,585,720

* Includes calender 1977 as well as fiscal 1976-77.

Source: Financial Services Branch, Ontario Ministry of the Environment

TABLE 5

ESTIMATES OF CAPITAL COSTS OF WATER POLLUTION ABATEMENT FACILITIES COMPILED FROM APPLICATIONS FOR CERTIFICATES OF APPROVAL - ONTARIO

($ 000)

Year	Basic Iron & Steel	Chemicals	Mining & Metal-lurgy	Petroleum & Petro-chemicals	Pulp & Paper	Total Approvals No.	Total Approvals $000
1967	1,469	1,112	2,064	813	778	65	10,827
1968	173	1,161	1,400	-	1,006	85	5,300
1969	531	2,276	958	-	5,686	116	15,080
1970	25	2,059	1,872	1,177	6,502	124	25,515
1971	12,983	3,837	13,301	2,084	6,519	140	42,904
1972	2,230	3,861	3,071	4,671	13,372	119	32,824
1973	3,804	867	37,101	3,489	5,323	75	52,558
1974	5,750	2,013	2,144	5,373	5,952	52	22,552
1975	4,849	11,941	5,812	6,025	3,434	93	31,136
1976	5,182	1,665	253	24,577	4,529	75	44,609
1977	350	9,010	2,356	10,742	16,537	44	41,201

Source: Files of the Industrial Approvals Section, Environmental Approvals Branch, Ontario Ministry of the Environment.

The capital expenditures implied by disbursements under the Ontario Pollution Control Incentive Act are presented in Table 4. Table 5 provides a summary of the estimated capital costs of water pollution abatement facilities as recorded on the Certificate of Approval application forms. These two sets of data are compared with total investment data in Table 6.

There are really no "official government" figures that capture all of the relevant industrial pollution abatement expenditures. The difference between the expenditures cited by the CPPA and those implied by the ACCA gives an indication of this understatement although the CPPA figures include some projects that contribute to productivity improvement as well.

Because of the generally poor quality of these industrial expenditure data, we cannot say with certainty whether or not pollution abatement expenditures have been overly burdensome to industry. Nor do these figures show that industry has accomplished very much in the way of pollution abatement. While the data are deficient with respect to the actual magnitudes of expenditure, they do reveal that manufacturing sectors have been devoting an increasing proportion of their investment spending to pollution abatement in recent years.

TABLE 6

ESTIMATES OF CAPITAL COSTS DERIVED FROM THE ONTARIO POLLUTION ABATEMENT INCENTIVE ACT DISBURSEMENTS AND INDUSTRIAL CERTIFICATES OF APPROVAL - ONTARIO

($ 000,000)

Year	Expenditures for Air & Water Pollution Control Implied by the Pollution Abatement Incentive Act (Fiscal Year 1 April-31 March)	Water Pollution Abatement Cost Estimates Compiled from MOE Certificates of Approval (Calender Year)	Total Investment - New Plant and Equipment - All Manufacturing Ontario
1970/71	$ 8.3	$ 25.5	$ 1,625.1
1971/72	38.9	42.9	1,332.0
1972/73	46.1	32.8	1,341.2
1973/74	22.6	52.5	1,635.4
1974/75	39.3	22.5	2,252.2
1975/76	46.3	31.1	2,860.5
1976/77	88.2	44.6	3,016.2
1977	-	41.2	3,260.4 (Prelim.)

Sources: Expenditure data - Tables 4 and 5.
Total Investment - Statistics Canada, #61-205.

These data represent, of course, past history. The real concern is, of course, the future costs of implementing pollution abatement projects and the timetables which governments give to industry to achieve these objectives. With respect to timing, it is clear to us that a few large polluting companies have systematically resisted implementing pollution abatement projects over the past decade presumably because of the large costs involved. Because these abatement projects were not undertaken ten years ago, the costs of doing them now have increased substantially. In these days of two digit inflation, procrastination will invariably result in higher costs for pollution control. Perhaps these firms believe that if they wait long enough, environmental regulations will just go away or at least be severely curtailed. Such expectations, I would submit, are entirely unfounded.

A few estimates of the costs of meeting Federal or Provincial government environmental objectives have been made recently, but only for the pulp and paper industry.[8] Such estimates have been useful to get a feeling for the orders of magnitude involved and they revealed the problem sectors in that industry. However, single-valued cost estimates hide the fact that there are usually many combinations of pollution abatement programs that could be implemented in a particular plant and which can achieve varying degrees of abatement at different costs. Single-valued cost estimates usually refer to just one of these alternative programs. It

is much more useful to generate Abatement Cost Functions for different firms or industries. With such a table, we can determine the costs of meeting specific abatement loading objectives. We can also see what a given budget would allow us to achieve and we could compare the costs of successive levels of abatement against the firm's financial resources. Finally, we can more clearly determine what it will cost to achieve specific environmental benefits that result from abatement.

JOBS AND THE ENVIRONMENT

Industrial spokesmen have long claimed that there must be trade-offs between jobs and pollution control. Implicit hints and overt threats of closures and unemployment have been used through the years by many firms to put off implementing pollution control. Indeed, the Ontario KVP Act of 1950 has served notice to this day that the operations of an industrial enterprise took precedence over proven environmental damages[9]. While the Act supposedly did not prejudice any rights of action against polluting companies for pollution damages, it has made environmental enforcement agencies in Ontario reluctant to use injunctions and closures as a method of enforcing pollution abatement in Ontario.

Subsequent to KVP, so far as I can tell, there have been no instances in Ontario of factory closures wrought

solely by an inflexible enforcement of pollution abatement standards or guidelines. There have been and there are today, factories and mills that would become, in a financial sense, uneconomic if all desired abatement objectives were met. However, many of these facilities are skating on the thin ice of insolvency for other reasons so that the removal of the environmental subsidy would finally break that ice, as it were.

We have investigated employment and other economic effects of increased pollution abatement costs on the pulp and paper industry in Canada and Ontario using an econometric model developed by Andrew Muller (1975) of McMaster University. With this model, we can simulate how industry participants would have reacted to changing demand rising costs, etc. over the test period of 1958-1974. It should be emphasized that the simulations generate the resulting values of output and employment over the study time period. They are not predictions of future output or employment changes. However, if we assume that firms in the industry will continue to react to future changes in costs in more or less the same way as they did in the past, then these simulations provide an indication of the magnitude and the direction of future consequences of cost changes.

We ran simulations of cost increases (for both capital and operating expenses) of 1%, 5% and 10% per year. That is, the industry would invest and spend an <u>extra</u> 1%, 5% or 10%

TABLE 7

"ORDERS OF MAGNITUDE" OF COST INCREASES
IN THE PULP AND PAPER INDUSTRY IN CANADA AND ONTARIO
WHICH WERE USED IN THE SIMULATIONS

Investment[1] ($ millions)

Year	Repair	New Capital	Total	Percentage of New Capital Investment 1%	5%	10%
Ontario						
1976	288.2	105.8	394.0	1.05	5.3	10.6
1977	269.4	128.7	398.1	1.29	6.4	12.9
Canada						
1976	469.8	720.3	1,190.1	7.2	36.0	72.0
1977	515.4	865.1	1,380.5	8.7	43.3	86.5

Expenditures on Labour, Energy, Supplies and Materials, 1974[2] ($ millions)

	Labour	Energy	Material Supplies	Total	1%	5%	10%
Ontario	203.9	84.4	556.4	844.6	8.4	42.2	84.5
Canada	802.8	409.2	2,306.7	2,796.1	28.0	139.8	279.6

Sources:
[1] Statistics Canada, Investment Statistics 61-007.
[2] Statistics Canada, Preliminary Bulletin - 1974 Annual Census of Manufacturers, Catalogue #36-204P, June 1976.

per year over the 16-year study period to account for the pollution abatement. Moreover, different assumptions as to whether abatement costs would be incurred in the U.S. and/or the rest of Canada were also tested. The orders of magnitude of these costs during 1976 and 1977 are presented in Table 7. These are the costs increases that would occur if these percentage increases were applied in 1976 and 1977.

The results for Ontario of six different simulation tests are presented in Table 8. It is clear that Ontario producers are affected most when abatement costs rise in Ontario but not elsewhere. Over the test period, a cost increase of 1% only in Ontario results in a fall in total Ontario production by an average 2%, an 11% decrease in output results from a 5% cost increase and a 22% Ontario production decrease is generated by a 10% cost increase. The corresponding declines in employment are .5%, 3% and 7%. In real terms, a 3% decline in employment in 1974 represented about 500 jobs in Ontario. Reductions in employment are not as large as reductions in output because there is an expected increase in employment to undertake abatement activities. Under the conditions simulated with tests 3 and 4, the employment and economic effects of increased abatement costs in Ontario might be considerable.

However, in the more likely instance that abatement programs are undertaken by producers in the rest of Canada and the U.S. as well as Ontario, the results differ drama-

TABLE 8

RESULTS OF SIMULATION TESTS IMPOSING POLLUTION ABATEMENT COST ON THE INDUSTRY

Average Percent Change in Ontario Variables 1958-1974*

Simulation Test	Total Ontario Shipments of Pulp & Paper (Value of Shipments of the Pulp & Paper Industry in Ontario (QGVRO)	Ontario Production of Newsprint (QNO)	Ontario Pulp and Paper Mill Production Workers (PWKO)
1. No shock	-	-	-
2. Ontario costs rise 1%	- 2.2	- .6	- .5
3. Ontario costs rise 5%	-11.2	-3.0	-3.0
4. Ontario costs rise 10%	-22.4	-5.9	-7.4
5. Ontario and Canadian costs rise 5%	.02	-0.01	8.5
6. Ontario, Canadian and U.S. costs rise 5%	.8	1.8	9.1

* Percentages are rounded to the nearest 0.1 percent.

Note: These percentages indicate the difference that would occur between simulations without pollution costs (Test 1) and simulations with pollution abatement costs.

Source: Land Use Co-ordination and Special Studies Section, Ontario Ministry of the Environment.

tically. Total Canadian and Ontario outputs do not change significantly while Canadian and Ontario employment show marked gains. The increased demand for labour for abatement activities dominates any reduction in employment as a result of the slight decline in output. The resulting increase in employment both nationally and provincially lies between 8% and 10% for these simulations.

In tests 2 to 5, it is assumed that abatement activities will result in the increase in equipment, labour, materials, supplies and energy requirements by equal amounts. If pollution abatement activities are capital intensive, requiring very little labour for surveillance and maintenance, then the employment effects may be overstated. On the other hand, these are first round employment effects and do not account for increased employment generated by the expenditures of the equipment manufacturing industry.

Obviously, these findings must be interpreted with care. But they give guidance in formulating policy and they indicate the economic conditions that will minimize our own losses as we enforce pollution abatement objectives. That is to say that if Ontario firms incur abatement expenditures in more or less the same proportions as elsewhere in Canada or in the U.S., Ontario companies will not lose their market shares nor will the province as a whole suffer any significant job losses.

The Organization for Economic Co-operation and Development convened a Special Session of the Group of Economic Experts in 1977 to examine claims that environmental policies have contributed to unemployment in OECD member countries. It was found that, in the short run, environmental protection programmes created at least as many jobs as they have destroyed; indeed in a number of countries they have increased the total number of jobs available (OECD, Environment Directorate ENV/ECO/SS/77.1)[10].

Another point to be stressed is that pollution abatement is a relatively good employment generator. Jobs are created in the design, construction and, often in the maintenance of abatement processes and equipment. Indeed, pollution abatement often requires little more than extra workers to watch gauges, check for spills and turn off valves. However, this flies in the face of industry's efforts to substitute costly labour with automatic machinery. Job losses result if factories are closed down. If the government's implicit or explicit policy is <u>not</u> to force closures purely for environmental reasons, then pollution abatement will only create additional employment.

<u>WILL CANADIAN INDUSTRY BECOME LESS COMPETITIVE</u>?

Associated with the employment issue is the assertion that Ontario and Canadian industries will become less competitive <u>vis-a-vis</u> foreign companies as a result of

pollution abatement costs. I fully agree that strong measures must be taken to increase the productivity and cost competitiveness of Canadian industry. However, like jobs and the environment, this complaint verges on being a non-issue as well. Our econometric study showed that Ontario pulp and paper producers would not lose their market shares as long as similar magnitudes of abatement costs are incurred throughout the rest of North America and there is every indication that this is happening.

To cite just one of many pieces of evidence on this point, the Stanford Research Institute prepared a report in 1976 entitled, "Investment Outlook and Related Federal Policies for the Steel, Plastic and Paper Industries, 1976-1985". This report noted that costs for pollution abatement were of concern in each of these industries. The following passage refers to the steel industry:

> "Environmental and health regulations may be expected to account for 22% of total capital investment for the period 1976-85 compared with 12% from 1970-75. Assuming costs are passed on to prices, such spending is not expected substantially to affect additions to capacity". (Stanford Research Institute, 1977, p. 5-18).

In November 1977, the Conference Board in Canada published a report entitled "Assessing Trends in Canada's Competitive Position: The Case of Canada and the United States." It is significant that pollution abatement

expenditures, or occupational health and safety costs for that matter, are not even mentioned, let alone identified as a determinant of Canada's competitive position.

One need only look at Japan to see the magnitude of the social costs that industry can exact from its people in order to become the world's leading exporter.

CAN INDUSTRY AFFORD POLLUTION ABATEMENT?

In 1976, I co-authored a report on the pulp and paper industry in which we wrote that, "Most pulp and paper mills in Ontario can 'afford' to control their pollution to a much greater extent than they are presently doing" (Donnan and Victor, 1976, Vol. III, p.47).

We actually came to that conclusion in 1974 with 1973 data being the latest available. It is gratifying to have this conclusion corroborated by two impeccable sources. The Canadian Pulp and Paper Association has verified that pollution abatement expenditures by that industry in 1976 increased by almost 60% over those in 1974.[11] Secondly, the recent discussion paper published by the Ontario Ministry of Natural Resources also confirmed the fundamental solvency of the pulp and paper companies and concluded that the industry could easily absorb the costs of pollution abatement alone (Ontario Ministry of Natural Resources, April 1978). However, the authors of the discussion paper

indicate that the industry would be hard pressed to raise the capital to finance both pollution abatement and necessary modernization.

Over the past two years, I have also had access to corporate data which more precisely indicates the financial impact of abatement costs on cash flows and profits. It is clear to me that, in these cases, certain levels of pollution abatement could absorb a significant portion of a company's cash and credit resources.

Nevertheless, there is no question in my mind that industry in Canada and Ontario have the funds to undertake the pollution abatement specified by our Ministry. It is just that, from the company's point of view, there are always better and more productive uses for available cash than pollution abatement. Of course, one might question the relative "productivity" of paying dividends, of building a new corporate headquarters or of giving top management a bonus. But, the basic problem, as I see it, is that firms lack effective financial incentives to allocate funds to pollution abatement.

However, I believe that we can bend our energies to more productive pursuits than debating these highly subjective issues or non-issues. My own reading of the comments of industrial spokesmen is that there should be a more rational and clear expression of abatement objectives

and a determination of the environmental benefits that are obtained from the various abatement projects. And from industry, I personally would like to see more results in terms of reduced waste discharges rather than a litany of plans, problems, excuses and requests for extending deadlines.

In the vast majority of contacts between the Ministry of the Environment and industrial polluters, solutions are reached that are satisfactory to both parties. But, in a few situations, such as the pulp and paper industry, steel mills, the Sudbury mining and smelting operations progress has been slow. This is because the costs of abatement in these situations are substantial, there are other claims on scarce financial resources and the benefits of additional levels of abatement are often not clear.

The following are some personal suggestions that could help in the development of abatement programs and the resolution of stalemates.

On the part of government more explicit guidance could be provided with respect to the following issues:

1. The environmental effects of different levels of abatement at specific polluting establishments could be systematically analyzed and made public.

2. Abatement priorities should be established for specific establishments, among establishments belonging to one company and perhaps among different regions in the province. The criteria used for establishing these priorities should be explicitly stated.

3. Initiate discussion of an economic implementation incentive policy such as a Pollution Control Delay Penalty.[12]

On the other hand, industry could:

1. Show good faith by implementing agreed to abatement measures that will achieve measureable reductions in emissions and effluents. In addition, refrain from asking for repeated extensions in Control Order and Program Approval deadlines.

2. Commit research funds to find new and effective ways of recycling, reducing or treating the pollutants that are quantitatively most important such as BOD_5 for the pulp and paper industry and SO_2 for the smelting industry.

3. As some companies have already done, provide the financial data necessary to make assessments of the impacts of abatement costs on mill profitability and employment.

For those industrial establishments that provide evidence of potential financial hardship, explicit environmental-economic trade-offs may be undertaken in the following manner.

ENVIRONMENTAL-ECONOMIC TRADE-OFFS

First and foremost, an Abatement Cost Function must be developed. Examples of these functions are presented on Tables 9 and 10. They essentially show the associated financial costs to the polluter of reducing the emissions of a given pollutant. Other effects such as added revenues and employment changes at each level of abatement could be included in these tables as well. If Abatement Cost Functions were available for all large dischargers into a specific watershed or air mass, they could be used to

TABLE 9

POLLUTION ABATEMENT COST FUNCTION OF WATER POLLUTION ABATEMENT PROGRAMS FOR A PULP MILL IN ONTARIO

Program Number	Annual Cost of Program Over 25 Years (In Present Value Terms)	BOD Discharges Tons/day
1	0	62.00
2	31,000	61.15
3	133,000	17.00
4	164,000	16.15
12	464,000	9.69 (7.5 MOE objective)
20	640,000	3.23
16	848,000	1.62

Source: Alternative Policies for Pollution Abatement: The Ontario Pulp and Paper Industry, Vol. I, p.357.

TABLE 10

POLLUTION ABATEMENT COST FUNCTION FOR AN ONTARIO PULP AND PAPER MILL
AIR POLLUTION CONTROL ALTERNATIVES WITH LEAST COST WATER TREATMENT
WHICH MEETS MINISTRY OF THE ENVIRONMENT WATER EFFLUENT OBJECTIVE

Water Pollution Control Program	Alternative Air Pollution Control Programs*	Total Inflated Capital Costs of Treatment ($ million)	BOD_5 Water Effluent Loading tons/day (MOE Objective: 14 t/day)	Particulates		H_2S	
				lb/hr (MOE Objective: 38.5 lb/hr)	% Reduction	lb./hr. of Sulphur (MOE Objective: 24.25 lb/hr)	% Reduction
1. Present condition	None	0	32	485	0	857	0
2. Treatment to meet objectives	SS, BLO1, BLO2, ST	35.15	14	485	0	40	95
3. "	SS, WS, BLO1, BLO2, ST	35.66	14	295	39	24.35	97
4. "	SS, P2, ST	36.65	14	249	49	822	4
5. "	SS, WS, P2, ST	37.16	14	59	88	806	6
6. "	SS, P2, BLO2, ST	38.03	14	59	88	321	63
7. "	SS, WS, P2, BLO1 BLO2, ST	38.33	14	59	88	24.25	97
8. "	SS, WS, P1, P2, BLO1 BLO2, ST	40.44	14	38.5	92	24.25	97

* Air Treatment Processes:
SS - steam stripping and non-condensable gases incineration.
BLO1, BLO2 - black liquor oxidation, treating stacks 1 and 2.
WS - Venturi type wet scrubber.
ST - Stack test.
P1, P2 - Secondary electrostatic precipitators, treating stacks 1 and 2.

Source: Environmental Approvals Branch, Ontario Ministry of the Environment (MOE).

define a least-cost abatement method for each discharger. This approach could also be used to design overall abatement program for all of the dischargers in a given watershed that would be most efficient from society's point of view. It would also help to identify an efficient abatement program irrespective of who actually pays the costs of abatement.

The abatement cost function as presented in Table 10 can be used to find an appropriate level of particulate and H_2S emissions from literally hundreds of possible permutations and combinations. The program listed in Table 10 are least-cost programs. Moreover, it is clear which programs are appropriate if H_2S reductions only are desired (program #3), if reductions in particulates but not H_2S are important (program #5) or if reductions in both contaminant emissions are imperatives (programs #7 or 8).

One can also determine whether there are any disproportionate jumps in cost from one abatement level to another as is apparent in Table 9. If one finds these jumps, or if costs of additional abatement are high and there is debate about the benefits of further abatement, then it would be useful to develop an "Abatement Benefit Function". These are tables that identify various effects of successively lower levels of pollution loadings. There are numerous methodologies "on the market" that one could use to identify and measure these benefits.[13] However, all are limited by the varying degrees of subjectivity required to implement them.

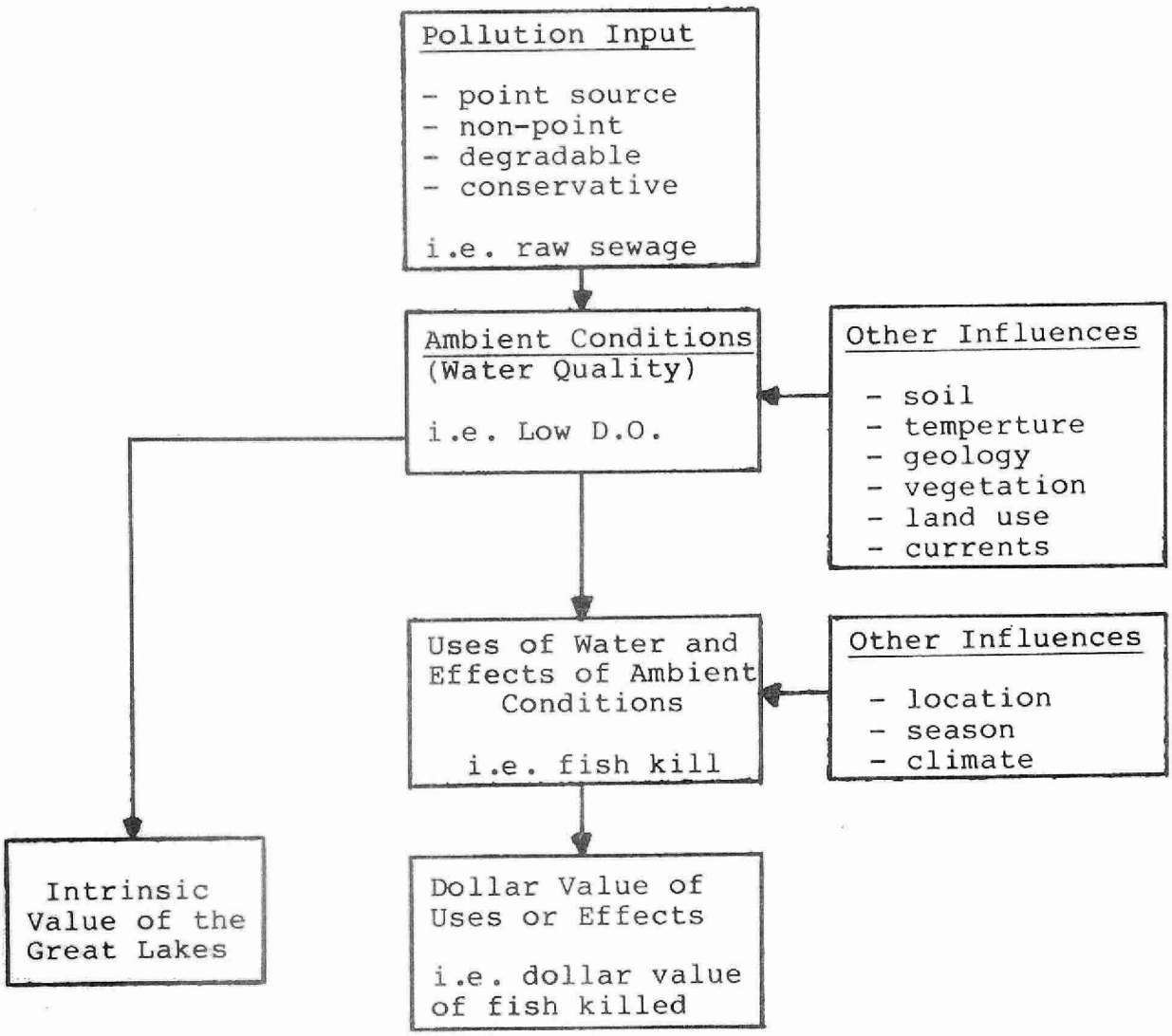
The approach for assessing the benefits of abatement that I am suggesting was originally developed for our 1974 pulp and paper study and is illustrated in Figure 1. This model implies that we need to understand more about how pollution inputs and changes in ambient conditions will affect human activities as well as the effects on the biota.

One set of benefits, that is to say, the effects or pollution damages that are reduced, are identified in Table 11. It would be ideal to measure the dollar value of reduced damages that result from successively lower emission levels. However, the best we can do at this time is indicate whether the benefit category is achieved or not achieved, I would expect, however, that my colleagues in the Ministry could probably measure some of these effects in the relevant physical units. For water pollution, we could measure human uses and health effects. We could also measure the occurrences of aesthetic effects such as smells, foaming, colour, etc. Likewise, for air pollution, we could measure the incidences of odour, soiling, corrosion, vegetation damage and, in some instances, chronic and acute health effects. There are two aspects of uncertainty and risk that must be mentioned. Many effects are subtle and take much research effort to sort out. The biological transport of mercury through food chains is an example of this. Second, some effects take years to manifest themselves. Our ambient air quality standards and most of the effluent loading objectives take some account of this risk element.

FIGURE 1

LINKING THE VALUE OF NATURAL WATER SYSTEMS

TO POLLUTION INPUTS



Source: Donnan & Victor, Alternative Policies for Pollution Abatement: the Ontario Pulp and Paper Industry, 1974, p.269.

TABLE 11

HYPOTHETICAL "ABATEMENT BENEFIT FUNCTION" FOR AN ONTARIO PULP MILL

BOD DISCHARGES (tons/day)	Associated Bacteria Levels (in this case, bacti levels are associated with BOD discharges* (Coliforms/100 ml)	Human Health**		Protection of Fish Life			Aesthetic Improvement				Comments
		Eliminate Public Health Threat	Permit Swimming[1]	Eliminate Fish Kills	Eliminate Fish Tainting	Improve Fish Habitat	Remove Sludge Deposits	Eliminate Smells	Eliminate Foaming	Eliminate Color	
62	10^6	No	No	No	No	No	No	No	No	No	These effects occur in a 40-mile long reach in a river into which wastes are discharged.
61	10^6	No	No	No	No	No	No	No	No	No	Dissolved oxygen sag and sludge deposits 40 miles downstream from mill.
17	10^2	No	No	Yes	No	Yes	Yes	No	No	No	Reduces area affected to 10 miles.
16	10^2	No	No	Yes	No	Yes	Yes	No	No	No	
10	<10	Yes	Yes	Yes	No	Yes	Yes	No	No	No	Reduces reach affected to 3.5 miles.
(MOE objective is 7.5 tons per day)											
3	<1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	
1.6	<1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	

Note: * All data in this column are imaginary.
** Human health is thought to be threatened only by bacteria in this situation.

Source: This is an hypothetical analysis. Information was derived from a specific mill situation. See Donnan and Victor (1974), Vol. I, Chapter IV.

To a certain extent, these effects are being measured and considered in negotiations with industry. But in the highly contentious abatement situations, we need more and better evidence of damages, risks and effects to justify the increasingly large expenditures for abatement. On the other hand, these tables might indicate that we do not need to reduce emissions quite so much to achieve substantial benefits.

The information in these tables contain much that is subjective and they will not deliver objective, value-free decisions on a platter. Negotiation and bargaining between agencies and polluters will have to continue. But the facts and figures assembled in these tables would allow both sides to argue from knowledge, not ignorance, and while the decisions will not be any easier, with this new information they have the potential to be much better.

CONCLUDING REMARKS

In closing, I have provided reasons why Ontario's environmental laws and objectives are not tougher than those of other jurisdictions. I have presented evidence to support my conclusion that environmental costs do not present a threat to jobs or to the international competitiveness of Canadian industry. Available data on past expenditures were presented and it was stressed that information about the costs of achieving successively lower levels of pollution abatement is far more useful than single-valued cost estimates. Two types of complementary environmental management instruments were identified: implementation incentives and financial assistance and I described the various types of financial assistance policies that are currently available to mitigate the impact of abatement costs on a company's profit position. I stand by my conclusion that industry can "afford" more pollution abatement but, I concede that it will be necessary to make some environmental-economic trade-offs in a number of industrial pollution situations. I have suggested a procedure for making these trade-offs at a specific polluting establishment in a rational, consistent and equitable manner.

Pollution abatement costs are by no means a drop in the bucket, but they are not the end of the world either. In fact, for most sectors of Ontario's industry, pollution

abatement costs have a rather minor impact on the overall cost picture. Some industrial sectors need tangible economic incentives, and perhaps some financial assistance, to get on with the job of implementing pollution abatement. On the other hand, we in the government must establish priorities based on evidence of environmental damages and risks and we must assemble the information required to make and justify rational environmental-economic trade-offs. This will require the inclusion of more science in our analyses and evaluations, but decision-making will remain, as ever, an art.

FOOTNOTES

1. Thomas J. Bell, "In a meeting of Ontario business leaders and members of the Provincial Cabinet", Tuesday, September 13, 1977. See also a series of full page advertisements in Canadian newspapers explaining the Industry's position.

2. John White, "Pollution: Duncan of Abitibi Calls for More Time", Canadian Pulp and Paper Industry, September 5, 1977, p.13. See comments by R.D. Duncan (1978), reports by Eco/Log Week (April 14, 1978, p.3) and by Smith (1971, p.iii). Evidently some politicians agree with these concerns as the Minister of the Environment, George McCague, has promised to temper our policies with common sense and ... take into account the economic factors which affect us today" (McCague, May 1, 1978, p.2).

3. See Dales (1968) and Haefele (1975) for a more thorough analysis of common property resources.

4. In 1950, the Ontario legislature explicitly and publicly gave employment precedence over pollution abatement when it passed a private bill, the Kalamazo Vegetable Parchment Act, which dissolved court injunctions against the mill which were restraining it from polluting the Spanish River. This mill, located in Espanola, Ontario, is presently owned by the Eddy Forest Products Ltd.

5. In September 1977, an Ontario trade mission to Japan headed by Premier William Davis was told that, among other things, Ontario's environmental regulations are too strict. Our media reacted strongly to this. See Norman Webster, Globe and Mail, September 29, 1977.

6. Under the 1972 Amendments to the Federal Water Pollution Control Act, a 1977 deadline was set applying best practicable control technology to all point sources other than publicly-owned treatment works. A 1983 deadline was set for achieving effluent limitations for categories and classes of point sources other than publicly-owned treatment works which require the application of the best available technology economically achievable.

7. This discretion has been critized. See the recent Hughes Commission Report (1978), pp.96-99 and 101.

8. See a report by Beak Consultants Ltd. (1971) published by Environment Canada and a discussion paper by the Timber Sales Branch of the Ontario Ministry of Natural Resources (1977).

9. For details of this case, see Donnan and Victor, 1974, Vol. I, p.78).

10. The OECD group of economic experts further concluded that "in the long run, even with the limited information available, it is reasonable to suggest that net job creating or job destroying effects would be small".

11. According to the Canadian Pulp and Paper Association, pulp and paper mills throughout Canada spent the following amounts on pollution abatement:

Year	1972	1973	1974	1975	1976	1977(prelim.)
Expenditure ($000)	47,088	27,463	66,074	92,693	104,716	137,408

Source: Personal communication with the Canadian Pulp and Paper Association.

12. See Donnan and Victor (1974), Vol. I, pp. 394-416; and Vol. III, pp. 68-79.

13. Useful review articles on this subject are Fisher and Peterson (1976, pp.19-25), Dewees, Everson and Sims (1975, Chapter 3) and Coleman (1977).

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CONCLUSIONS

1. Ontario's environmental objectives are not more severe than those in other jurisdictions.

2. Expenditure data poor.

3. Environmental management policies:

   a. Implementation incentives.

   b. Financial assistance.

4. Costs are mitigated by:

   a. timing,

   b. ACCA,

   c. sales tax exemptions.

5. Initial impact of costs (cash outlays or debt) is substantial.

6. Pollution abatement creates jobs.

7. International competitiveness largely unaffected.

8. Industry can afford pollution abatement, but:

   a. some sectors will be burdened.

   b. economic incentives needed to get on with the job.

   c. some sectors may need financial assistance.

9. Make environmental-economic trade-offs explicit.

addendum

This is a revision of the paper originally prepared for presentation on the 19th of June. No changes in conclusions have been made nor has any material been omitted. The revisions were made to improve style, clarity and readability; to correct a few minor factual errors, and to add further documentation. Table 11 was changed slightly to eliminate the impression that BOD_5 threatens human health. The measure BOD_5 itself does not indicate whether toxic or harmful substances are present. Other tests must be made to determine and confirm this.

THE ROLE OF ECONOMICS IN ENVIRONMENTAL STRATEGIES

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Two major issues in designing a pollution control programme are: 1. determining how much pollution control (or environmental quality) is desired; and 2. selecting and implementing a policy to achieve that environmental quality. The first issue involves evaluation of the costs and benefits of pollution control, which has already been discussed by Jack Donnan and raises economic, social, and political questions. I will not address that question, but rather assume that somehow through an analytical or political process there is a concensus about the environmental goals in a region with respect to a particular pollutant or group of pollutants. This paper then will focus upon the second question: how do we get there from here? What legislative, regulatory and other steps must be taken if a concensus about environmental goals is to be translated into action that will reduce emissions and achieve those goals?

It is frequently thought that meeting a specific environmental objective is primarily a technical problem. According to this school of thought, one can work backward from the desired environmental objective to the allowable emission rate for a particular source, and then perform an engineering study to determine the equipment necessary to achieve the necessary emissions reduction, and the cost of installing and operating that equipment. In some cases, we find absolute technical barriers because no technology exists for dealing with a specific pollution problem. In many more cases however technology may currently be available, yet it is not in widespread use.

One could identify technological means of pollution control that have been proven feasible and whose adoption would "solve" a pollution problem, yet these technologies are not employed. In short, we frequently do not use the knowledge and skills that we possess. If we examine cases in Ontario, it is easy to conclude that the biggest problem in achieving environmental objectives is not finding the technical solutions, but uncovering and implementing the "soft ware" - the legislative and regulatory rules and policies that will provide the stimulus necessary to induce various sources to invest in capital, change their production processes, maintain their equipment and otherwise implement a pollution control strategy that will satisfy the environmental goal.

The purpose of this paper is to discuss in general terms a variety of pollution control policies and to evaluate these alternatives. The alternatives to be considered range from regulations and legislation that are familiar to all of you to proposals that have been widely discussed but not implemented in the environmental area. The following is a brief summary of four major types of pollution control policies:

a. Standards and fines. The traditional approach to controlling pollution emissions is to establish emission standards and impose fines for exceeding those standards. An example of this approach would be legislations specifying that it is "...unlawful to discharge waste water containing more than 300 parts per million of BOD into the environment. The penalty for violation of this section shall be up to $1,000 per violation".

b. Effluent standards and proportional fines. A modification of the traditional approach contains the usual prohibition, but the penalty for violating the standards is proportional to the degree of the violation. Thus one might be prohibited from discharging more than 300 parts per million of BOD, and be required to pay X cents per pound for all BOD discharge in excess of the specified limit. This differs from the traditional approach primarily in that the penalty for violation is predictable and easily calculated for all parties, rather than being at the discretion of a regulatory agency or court.

c. Effluent charge. This is a requirement that the discharger of specified wastes pay a specified amount for their discharge. For example, one could require that all discharges of BOD within a specified area require that the discharger pay 5¢ per pound for this discharge, to be paid perhaps to the local pollution control authority. Under this system, there is no specific standard to be violated. It simply becomes expensive to discharge wastes.

d. Pollution rights. Under a pollution rights scheme, the pollution control authority would specify the total amount of a pollutant that was allowed to be discharged within the area of its jurisdiction, perhaps a lake or watershed. Permits would be created for discharging fractions of the total allowable discharge, and would be sold to the highest bidder. It would

be unlawful, and severely punished, to discharge wastes in the absence of such a permit, or in excess of the amount allowed by the permit.

As you can see, two of the policies that will be discussed here are almost without precedent in the environmental field. I will argue below that these policies have some significant advantages over current methods for dealing with some pollution problems. They have been seriously discussed at numerous conferences involving government and industry as a means of solving persistent compliance problems. The next section of this paper will present a set of criteria for evaluating policies. In section III, we will discuss these policies in detail and evaluate them according to the criteria developed in section II. Finally, section IV will present some conclusions and indicate the status of the alternative policies with respect to research, discussion, and practical experience.

Criteria for Evaluating Policies

In order to choose among alternative policies for pollution control, it is necessary to have some set of objective criteria by which these policies may be evaluated. We will consider five specific objectives or criteria in this section. These are:

1. the ability to achieve a given degree of clean up at the least cost;
2. an incentive to comply rather than to argue about the policy;
3. confidence in the degree of pollution control;
4. confidence that pollution control costs will be limited;
5. the financial burden upon the pollutors.

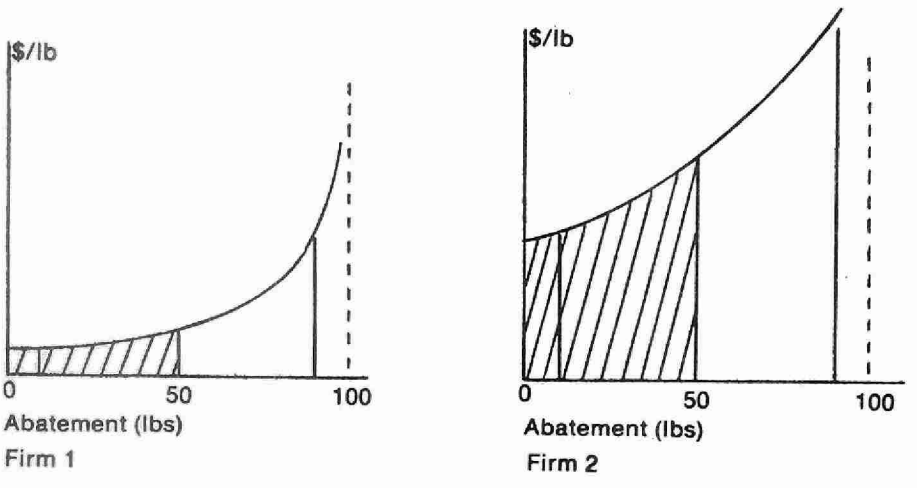
One of the most important characteristics of a pollution control policy is its ability to encourage pollutors to achieve a given degree of pollution control at the least possible cost. Consider a situation in which several pollutors discharge their wastes into a single body of water. Suppose that the cost of controlling pollution for each pollutor is very different, as a function of the degree of pollution control. Figure 1 shows hypothetical pollution control cost curves for two firms. The horizontal axis shows the pounds of pollution controlled ranging up to 100 pounds per day which is assumed to be the initial discharge rate. The vertical axis is the incremental cost of removing each pound of waste from the discharge, and in both cases this cost is shown to rise with the degree of pollution control. Obviously firm 2 experiences much higher incremental costs than firm 1. The area underneath the incremental cost curve is the total cost of abatement.

Looking at Figure 1, it is clear that requiring both firms to clean up 50 percent of their waste will impose much higher costs on firm 2 than firm 1. Furthermore, because the incremental cost of reducing emissions by one pound for firm 2 is far above that for firm 1, the same total abatement of 100 pounds per day could be achieved at a lower cost by firm 1 engaging in much more cleanup, and firm 2 engaging in much less. If the same 100 pounds of abatement were achieved by controlling 90 pounds from firm 1 and 10 pounds from firm 2, the increased costs at firm 1 would be the area from 50 to 90 under the incremental cost curve, while the cost saving at firm 2 would be the area from 10 to 50 under its cost curve. Since the former is substantially smaller than the latter, it is clear that reallocating this cleanup primarily to firm 1 would save a considerable amount of money. The general principle demonstrated

FIGURE 1

INCREMENTAL COST OF POLLUTION ABATEMENT

OF TWO FIRMS WITH DIFFERENT COSTS



here is that total costs of pollution control will be minimized when control is undertaken first by those firms that have the lowest incremental cost of pollution control, and is carried out until the incremental cost of controlling emissions by one additional unit is equal at all firms.

The discussion of abatement efficiency above assumes that the pollution control costs for each firm can be represented by a curve of the type shown in Figure 1, and that this curve is reasonably well defined. If there are opportunities for substantial technological progress, then cost curves can shift over time, and the analysis must take into account the possibility of these shifts. In this case, one must consider which policies will cause the cost curve to shift downward most rapidly.

The second criterion for evaluating pollution control policies is their ability to create incentives to control pollution rather than fighting about regulations. In some cases, the issuance of pollution control rules and regulations leads not to immediate efforts to reduce pollution emissions, but rather to calling out legions of lawyers and technical experts to argue about the fairness of the regulations, their technical feasibility, and their economic impact. In some cases, dire predictions are made that if the regulations are enforced plants will close and thousands of workers will be laid off, to join the ranks of the unemployed. When this kind of threat is credible, it can paralyse the pollution control programme, since a politically responsible agency, and in fact any sensible citizen, must be concerned about public policies that have severe economic repercussions, especially when jobs are at stake.

One can identify other cases however where the issuance of regulations leads to minimal dispute over the regulations themselves, and the primary effort being directed toward compliance with those regulations. Because the resources of any firm are limited, the less effort that is placed on fighting against the regulations, the more resources are available for actual compliance. The technical expert who is testifying to the infeasibility of compliance cannot simultaneously be engaged in designing pollution control equipment.

Perhaps most important, if it appears that arguments of technical infeasibility will lead to postponement or relaxation of the regulations, there is a strong incentive not to search for technological breakthroughs that make compliance feasible. On the contrary, once one has argued that the compliance will be too costly or impossible, and this strategy appears to have some possibility of success, there is a strong incentive not to perform R and D that would weaken this position. Thus policies that are less subject to attack on the grounds of technical or economic infeasibility will have the additional advantage that they encourage firms to put their best efforts into compliance rather than argument.

The third criterion is the confidence that the policy will achieve the desired degree of pollution abatement. To some extent of course this confidence will depend upon the vigour with which the policy is implemented and enforced. However assuming a given level of enforcement, we will see that some policies will inherently provide a high degree of certainty about the extent of pollution control, and therefore the resulting environmental quality. Other policies however because of some built in flexibility, are less certain in this regard.

In such cases, it may be necessary to trade off a lower degree of certainty about the extent of pollution control against some other advantages of the policy.

Whether certainty is important or not in a particular case may depend upon the consequences of the pollution discharge. In some cases, the incremental effect of one pound of additional discharge may be roughly the same over a wide range of ambient quality levels. In this case, the precise degree of pollution control is not particularly important: what is desired is to effect some reduction in emissions. In other cases, however, there may be a threshold effect, or some ambient quality level at which very serious consequences occur. In these cases, it may be very important to maintain ambient quality that is better than this threshold level. Here, it may be far more important to achieve a specified degree of abatement, than it is simply to make some progress in clean up. For example, if the survival of particular fish species requires five parts per million of dissolved oxygen in the water 90% of the time, then an increase in average DO levels from 2 to 3 parts per million will be of little value: there will still be no fish. It is only if DO levels can be raised to 5 parts per million or better that the substantial benefits from this pollution control appear.

A fourth criterion for evaluating policies is the degree of confidence about the upper limit of pollution control costs. Some kinds of policies that specify a specific degree of pollution abatement may have no inherent upper limit on the costs that could be imposed on firms. If the technology for that degree of abatement is not currently proven, then the cost of compliance might be very high indeed, or compliance may in fact be impossible without closing down the source. In other

cases, the technology may be proven, but the cost of implementation may vary enormously from one situation to another, and be highly uncertain in the absence of specific engineering estimates for particular firms. In this case also, the maximum possible cost may be unknown, and perhaps very high. In such cases, a policy that is more flexible, in not requiring a specific degree of pollution abatement from particular firms, may be able to specify an upper limit on the maximum pollution control cost that would be experienced. Often, however, policies that reduce the risk of imposing very high costs on some pollutors will score poorly on the previous criterion of ensuring a specific degree of abatement. Where the cost of pollution control is still uncertain, there is essentially a trade off between being certain of the degree of pollution and uncertain about the total cost, or being certain about the maximum necessary costs, but uncertain about the degree of pollution abatement that will buy.

Finally, we will consider the total financial burden on the polluting firms. Clearly efficient policies as described in the first criterion will impose lower financial burdens on all firms than will less efficient policies. In addition, however, some policies may require payments by firms above and beyond their expenditures for pollution control equipment. These payments may be the payment of fines for violation of pollution control orders, or the payment of fees for discharging uncontrolled wastes. Other things being equal, policies that impose a lower financial burden on firms would clearly be more desired by industry.

In discussing alternative pollution control policies we will have in mind two types of cases. The first case is that of the isolated

single pollutor. This might be a pulp and paper mill, or any other large industrial establishment located far from any other major pollution source. In this case, the single pollutor can be treated in isolation with respect to the airshed or watershed that is of concern. A second case is one in which there are a substantial number of pollutors located within the same air or watershed. We will assume for the sake of convenience that in the second case, the air or body of water is perfectly mixed, so that one pound of discharge of a particular pollutant from any firm is equivalent in its effect to a one pound discharge from any other firm.

Evaluation of Policies

A. Standard and Penalty

The traditional regulation by establishing emission standards and imposing penalties for exceeding those standards is one with we have at least a great deal of experience. The criterion of efficiency is not relevant to the single firm, but is relevant to the case with a large number of firms. If the policy is applied in a simple manner, requiring the same degree of pollution abatement, or the same emission standard for all firms, the policy does rather poorly. Where different sources have different pollution control cost functions, the requirement of uniform abatement will impose not only different total costs on different firms, but different incremental costs. Whenever the incremental costs are not equal among all firms, then reducing the degree of abatement at a high cost firm, and increasing it at a low cost firm can achieve the same total abatement at a lower total cost. This higher level of effiency

can only be achieved under the standard and penalty approach if the standards imposed are different for every firm, and based upon a detailed knowledge of the abatement cost function for that firm. While this case by case approach is not unheard of, it does require time consuming and costly investigations by the pollution control authority.

With regard to the incentive to pursue pollution control rather than fighting regulations, the traditional approach ranks poorly. If the regulations are reasonably strict, in that they require a substantial degree of abatement from different firms, it is often plausible to argue either that the technological capability does not exist, or that the cost would be too great for the firm, or the industry to bear. Many times, the issuance of proposed effluent regulations are met by cries that they will bankrupt the industry, and that thousands will be thrown out of work. While these cries of alarm may in some cases be well-founded, the problem is that it is very difficult to evaluate them. Unless the pollution control agency has good data on the abatement cost curve for each firm, and knows enough about the firm and industry financial picture to have some assurance as to the ability of the firms to withstand these costs, the argument of hardship will be credible and politically frightening. If the firms are being asked to push back the frontiers of technology, it will be virtually impossible to disprove arguments of technological infeasibility. Thus this approach is almost an ininvitation for argument, except in the uninteresting case where the requirements are so modest that they are clearly achievable at trivial costs.

With respect to confidence in the degree of pollution control, this policy does reasonably well. Because the emission rate is specified, one can calculate what ambient environmental quality would be achieved if the regulations are complied with. The only real uncertainty about the degree of environmental quality that will be achieved arises from the uncertainty that the regulations will actually be complied with because of the incentive problem.

Just as the confidence in the degree of abatement is reasonably high with this policy, confidence in the upper limit of control costs is relatively low. In the absence of detailed information about the cost functions for individual firms, or the industry as a whole, one can only estimate the total cost of pollution control. If the regulations are pushing upon the frontiers of technology, it is always possible that the costs may be very high indeed. There is nothing in the format of the standard and penalty that would limit such high costs. Furthermore, it is possible that individual firms may because of their particular equipment or situation find that their costs are enormously above the typical or average costs for the industry. Unless investigations have been made of each individual firm, such cases may not be identified before the regulations are put into place. Thus, in the absence of detailed studies by the pollution control authority, it is possible that a strict programme of standards and penalties could impose very high costs on some firms. It is this very fact that contributes to the perverse incentives referred to above to argue rather than comply.

The financial burden on the firms consists almost entirely of the cost of the pollution control equipment and its operation and

maintenance. Generally speaking, the fines levied under such programmes are very small, and insignificant compared to the actual costs of pollution abatement.

B. Standard and Proportional Fine

This policy differs from the policy just discussed in that the magnitude of the penalty for violating the emission standard is proportional to the degree of violation. In fact, this can be implemented either as a criminal fine for violation, or as a simple payment for exceeding a specified emission level. The latter case is best exemplified by the sewer surcharge, in which firms discharging extra strength wastes into municipal sewer systems pay to the municipality an amount calculated to equal the increased cost of treatment by the municipality for this extra strength waste.

The efficiency of this policy is somewhat better than that of a simple emission standard, since this policy allows high cost pollutors to discharge and pay rather than cleaning up. Because the proportional fine or fee for discharging beyond the standard applies a uniform pressure to all pollutors, it will tend more to equate the incremental costs of abatement among various firms. This in turn will tend to minimize the total cost of pollution control. Thus sources with inexpensive pollution control cost functions will clean up, while sources with high costs will pay.

The incentive characteristics of this system are substantially better than those of the traditional standard and fine approach. If the proportional penalty for exceeding the standard is designed to be not too

onerous; to apply pressure but not unbearable pressure to clean up, then it will be very difficult for any firm to argue undue hardship. The argument that it was impossible to meet the standard will be met by a request to do the best possible, and pay for any excess emissions. If the payment is properly calculated, this should give rise to no threats of closure and lost jobs. In short, by introducing a degree of flexibility into the programme, the incentive to argue that impossible burdens are being placed on sources is greatly reduced.

A corollary of the improved incentives however is a reduced confidence in the degree of cleanup. Precisely because the firm facing high costs or an impossible technological problem is allowed to pay rather than cleaning up, one cannot be certain how much cleanup will result. One could only be certain about the degree of cleanup if one had detailed cost information for each firm, and therefore predict in advance what each one would do.

Just as confidence in the degree of cleanup is reduced in this programme, confidence in the maximum cost is increased. With the standard and proportional fine, it is possible to calculate the maximum pollution control cost for any firm by calculating the payments that would be made given existing emission rates. This simple calculation would quickly allow the pollution control authority to determine the maximum burden on each firm, and therefore to evaluate arguments about unreasonable pollution control costs.

The financial burden on firms will in general be somewhat less than than that of the more rigid standard approach. While some firms under the proportional fines system will be paying monies to the pollution control authorities for discharging wastes in excess of the standard,

they will presumably do so only because this is less expensive than actual clean up. Thus as compared to being required to meet the standard, the financial burden on the firm here is reduced.

C. Effluent Charge

The effluent charge goes one step further towards designing a flexible system with decentralised decision-making. No emission standard is set, but a specified price must be paid by every pollution source for discharging wastes.

In the case of a number of pollutors into a single body of air or water, the efficiency characteristics of the effluent charge are excellent. If all sources are paying an equal amount for every pound of waste discharged, they will tend to reduce their emissions until the cost of further emission control is just equal to the price of an additional unit of waste discharge. Thus the incremental cost of pollution control will be equal for all sources, and the minimum cost of pollution abatement will be achieved.

Similarly, the incentive to abate rather than debate is excellent. There is no pay-off to arguing that a given degree of pollution abatement is technologically impossible or unreasonably expensive, since no specific degree of pollution abatement is required. So long as the charge is calculated not to impose an unreasonable burden upon industry, the argument that it will be impossible to achieve a given degree of clean-up may be met by a sympathetic hearing and a specification of where to send the cheque for discharging the expected amount of waste. If a firm can develop some improved technology that achieves greater degree of pollution control than was previously possible, or lowers the cost

of pollution control, it has every incentive to adopt this technology to reduce its effluent charge payments. There is no fear that discovery of better technology will lead to more stringent emission standards, since there are no standards.

The very flexibility of the effluent charge system means that confidence in the degree of pollution abatement is relatively low. Unless one has a reasonable estimate of the cost functions for most firms, it will be difficult to predict how much abatement will result from a given charge level. Thus this policy is good at applying pressure for pollution abatement, but poor at achieving a specified degree of abatement.

As a consequence, of course, the confidence in the maximum cost that is imposed on pollutors is very good. Once again, it is easy to calculate the maximum cost for each source as the effluent charge times the present rate of effluent discharge. Since most firms would find it economical to engage in some abatement, the actual cost would be less than this maximum. Thus the maximum financial impact can easily be determined with no knowledge of the abatement cost functions for each firm.

It should be clear however that as compared to either of the previous policies, the financial burden on the industry will probably be larger. Not only will most firms incur some costs for pollution abatement, all firms will pay some amounts for their remaining pollution discharge, unless they elect one hundred per cent abatement. While the efficiency characteristics of this policy will reduce the cost of pollution abatement, as compared to a simple effluent standard,

this may be more than offset by the amounts paid as effluent charges.

D. Pollution Rights

The final policy to be evaluated is the issuance of pollution rights. This is not a policy that would be appropriate for the isolated firm; to specify pollution rights for the single firm would be like setting an emission standard for that firm. The policy is generally suggested for the case of a large number of pollutors on a single airshed or body of water. The pollution control authority would specify the total emissions to be allowed in that area, and then would sell rights to discharge emissions the total amount of which equalled the desired allowable amount in that area. Individual firms would bid for these rights, and a secondary market would be established whereby excess rights could be sold, and newcomers to the area could attempt to purchase rights from existing holders.

The efficiency characteristics of a pollution rights scheme are exactly equal to those of the effluent charge. That is to say they are excellent. Because a market in rights would be established, all firms would pay the same amount per unit of discharge allowed. This once again would equate the marginal cost of pollution control among all sources, and minimize the total cost of pollution control.

The incentive to comply rather than argue is also just as good as in the case of the effluent charge. The firm that felt it was technologically infeasible to reduce its emissions would simply be told to buy a sufficient number of rights to allow it legally to discharge at its current rate. Because no specific firm is told precisely how much to clean up, no firm can argue that its burden is impossible. The best strategy therefore is to go about the job of controlling emissions with as much skill and energy as possible.

Unlike the effluent charge, the confidence in the degree of abatement from effluent rights scheme is very high. This policy specifies the total allowable emissions for the area, so that if compliance is achieved, confidence in the environmental quality will be as high as in the traditional effluent standard situation. Because the incentive effect and efficiency consequences of pollution rights are greater than under the traditional approach, the overall confidence in the results should be substantially improved. In short, there is a specification of the desired environmental quality, and a greater probability that this will actually be achieved, because of the flexibility in allocating the abatement burden among firms.

Conversely, the confidence in the maximum cost of pollution control is substantially less with pollution rights than it is with the effluent charge. Because the total quantity of pollution is specified, rather than the price per unit of pollution, it is not possible to determine beforehand what will be the market price of the pollution rights, in the absence of substantial information about the cost curves of the various emitters. While costs are less uncertain than in the case of effluent standard, since there can be some reallocation between high cost and low cost firms, it is still not bounded from above.

Finally, the financial burden on firms from a pollution rights scheme will be similar to that of an effluent charge scheme, that is to say probably higher than under a traditional effluent standard approach. Firms must pay not only for their pollution abatement but also for the purchase of rights to discharge their remaining emissions.

However the burden of this financial payment to the pollution authority is somewhat tempered by the reduction in abatement cost as compared to an effluent standard resulting from the efficiency characteristics of the market mechanisms.

Summary and Perspective

The above discussion may be taken to demonstrate that there is no perfect pollution control policy. While some policies score high in efficiency and in creating proper incentives, others score high in limiting the maximum expected pollution control costs or in the degree of confidence that a given degree of abatement will be achieved. There are clearly some trade-offs to be made in designing pollution control policies, and the choice will depend in part upon one's evaluation of the relative importance of the different criteria discussed here. It should be clear however that there are some advantages in moving away from the traditional approach of specifying an emission standard and threatening terrible consequences if that standard is not met. If the consequences for failing to meet a standard are in fact quite small, as has often been the case, there is little incentive even to embark upon a serious pollution control programme. If the consequences are extremely severe, as some environmentalists would like, then there is every incentive to argue that the standard cannot be met and that the economic consequences of the penalty will be disastrous. The reality of politics has made this an effective bargaining tactic for many years. The result is frequently that a rigid standard is postponed or watered

down until the burden is so minimal that no-one could worry about its effect.

The other three approaches discussed here, which may be characterised as more flexible or "market like" approaches, reduce some of these problems, although each presents some problems of its own. Specifying a price for emissions introduces flexibility in that it is no longer helpful to argue technological infeasibility. Furthermore, there is a limit to arguments about financial burden, since the maximum financial burden can easily be calculated. The incentive to develop better and more effective pollution control measures is great, since any improvement in pollution technology results in savings in effluent charges paid by the firm. In this respect, pollution control becomes just like any other aspect of running a business. Use of the environment to carry off wastes costs money, through the effluent charge, so that any reduction in the demand for this factor of production will result in cost savings. The usual incentives for cost control that are so effective in Canadian industry now can begin to apply to pollution control as well.

Finally, a system of pollution rights may have some desirable characteristics in particular situations. Where it is regarded as important to achieve a given degree of cleanup, rather than simply applying a uniform amount of pressure as in the case of the effluent charge, the pollution rights scheme gives more flexibility than a traditional emission standard, while providing greater certainty that the environmental objective will be achieved. A particularly appealing case for pollution rights might be made where the concern

was not to reduce emissions, but to prevent their increase in an area. By issuing pollution rights for the existing amount of pollution, one could ensure that environment was not degraded by economic growth, since new firms moving in would have to bid rights away from existing firms, resulting in some reallocation of pollution loads, but no total increase. Any other policy, whether effluent standard or emission charge, could lead to emissions in an area growing over time along with economic growth.

The suggestions I have made today may sound radical to some, but they are certainly not new. Economists have been arguing for effluent charges for over 15 years, and it was just 10 years ago that John Dales wrote his classic piece on pollution rights. The intervening years have seen little enthusiasm by practitioners for the kind of mechanism that has been discussed here. Some of this lack of enthusiasm may stem from a failure to understand the characteristics and workings of the proposed policies. Some opposition to the effluent charge however is well grounded in the difficulty of establishing a proper charge, and the difficulty of estimating what the consequences of such a charge would be. It must be remembered however that the choice is not simply between traditional approaches and a pure effluent charge. The mixed approach that was suggested above of the effluent standard with a flexible fine combines some desirable characteristics of both systems, and reduces the problem of setting a proper effluent charge, since that charge is not the only factor that determines the final degree of abatement. This mixed approach is becoming widespread in "sewer

surcharge" schemes across Canada. Furthermore, the effluent rights scheme avoids the problem of setting a price altogether, and leaves that to a market mechanism.

During the last decade, public demands for environmental protection have risen enormously, and it will take time for those who have previously used the environment without opposition to adapt to those new demands. It is clear however that we have not done as well as we might in achieving environmental objectives nor in applying proven technology to existing situations. In many cases, progress in developing new and more economical technology for better environmental protection could have been better. If we are to enjoy both a prosperous economy and a satisfactory level of environmental protection, we need to do a better job of utilising techniques that are already proven. We also need incentives to call forth the best efforts of Canadian industry toward developing better and more economical technology for pollution control. Only the sensible use of the best possible administrative policies for pollution control will call forth the best efforts of industry to meet this challenge. Pollution control agencies and industry alike must seriously consider not just the traditional and familiar regulatory methods, but the whole variety of policy instruments that are available if we are to replace delay, inefficiencies, and debate with progress, efficiency and abatement.

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SESSION II

Chairman: Dr. J. A. McCoubrey
Manager, Lambton
Industrial Society,
Sarnia, Ontario

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Supervisor, Phytotoxicology Section, Ontario
Ministry of the Environment

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Phytotoxicology Fluoride Studies in Ontario

by
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The principal objective of the Phytotoxicology Section is to provide comprehensive knowledge on the effects of air pollutants on vegetation of all types throughout Ontario for environmental management purposes. This overall objective is pursued in three ways:

1. By investigating complaints concerning suspected air pollution injury to all types of vegetation, which include forests, orchards, farm crops, and ornamental plantings, in both rural and urban areas. In doing this it is necessary to differentiate pollution injury from similar injuries caused by insects, disease, adverse weather, poor nutrition, and mismanagement. The Environmental Protection Act has made provision for a Board of Negotiation to mediate the settlement of claims of persons whose vegetation or livestock have been damaged by air pollution and have suffered an economic loss.
2. By conducting assessment studies in areas of concern where adverse effects on vegetation may occur as a result of emissions from existing or proposed industrial sources of air pollution. Over 100 industrial sources were surveyed in 1977.

3. By carrying out practical research studies in controlled environment greenhouse and growth chambers on the effects of air pollutants on vegetation, on differential diagnosis of contaminants, to test anti-pollutant materials, to screen resistant plant species, and to determine air quality standards and criteria which may be applicable for the protection of forestry and agriculture.

To carry out these studies the staff complement of the Phytotoxicology Section consists of plant and forest pathologists, agricultural specialists, plant ecologists, a histopathologist, a biostatistician, and greenhouse and laboratory technicians. The Phytotoxicology laboratory and headquarter offices are located in Toronto, and associate northern regional offices are located in Sudbury and Thunder Bay.

In the Phytotoxicology laboratory, about 10,000 vegetation and soil samples which are collected annually during complaint or assessment visits are examined by pathological and histological techniques, and processed for chemical analysis. A herbarium is maintained to demonstrate, compare, and diagnose plant material damaged by particular air pollutants.

In addition to investigating air pollution vegetation complaints, the Phytotoxicology Section conducts continuous ecological studies throughout Ontario to determine the occurrence, severity, and extent of air pollution vegetation injury. The significance of these studies in areas of

concern is that if ambient air quality records in conjunction with vegetation data show that the biological component of the environment is in danger, then prompt abatement action is taken. In the vicinity of industries under a Control Order issued by a Regional Director, the air quality and vegetation studies indicate whether beneficial effects are occurring as a result of the Order. In addition, assessment studies are conducted in agricultural or forested areas prior to a major industry becoming operational in order to determine the pre-operational endemic conditions which are indigenous to the area.

Vegetation is ubiquitous and readily serves as a monitor of air pollution. It is less expensive to establish a large number of vegetation surveillance stations surrounding a source of air pollution than setting out a network of electronic air sampling instruments which require frequent servicing. This is recognized by combining vegetation and air quality monitoring surveys in the vicinity of industries.

In the course of Phytotoxicological investigations a number of contaminants have been encountered. These include fluorides, sulphur dioxide, photochemical oxidants, lead, boron, nickel, arsenic, salt spray, ammonia, and various types of dusts.

FLUORIDES

With regard to fluorides, several kinds of industries are under investigation which have the potential to affect vegetation in Ontario. These industries include manufacturers

of phosphate fertilizers, hydrofluoric acid, fiberglas, steel, uranium hexafluoride, petroleum products, brick, ceramic, frit, glass, and aluminum.

There is considerable variability in response to atmospheric fluorides by various plant species and varieties. Sensitive plant species are affected by an average of 1.0 ppb fluoride for 24 hours, and by an average of 0.5 ppb for 30 days. When fluorides accumulate in plant leaves beyond certain threshold levels, which varies with different plant species, leaf injuries occur. Certain sensitive gladiolus varieties can display leaf injury with only 20 ppm fluoride in their leaves, whereas it has been found that bitternut hickory can concentrate up to 1000 ppm fluoride in its foliage without showing any visible injury. Gladiolus, apricot, plum, St. Johnswort, sweet corn, grape and developing needles of pines are most sensitive to fluorides. Soft suture of peaches was found to occur when the atmospheric levels of fluoride exceeded 44 ug collected on 100 cm^2 of filter paper over a 30 day period.

Farm animals may develop the disease fluorosis by feeding on fluoride-contaminated forage crops over an extended period of time. Cattle are most sensitive, followed by sheep, horses, swine and poultry in decreasing sensitivity. Animal feed should not be in excess of 40 ppm fluoride (dry weight basis) on an annual average based on monthly sampling, in order to avoid the adverse effects of the disease.

The following are results of some of the fluoride investigations conducted by the Phytotoxicology Section during the past 10 years.

FERTILIZER MANUFACTURER

Studies have been conducted annually in the vicinity of International Minerals & Chemicals Corp., (IMC), formerly ERCO, at Port Maitland since 1968. Prior to 1968, emissions from fertilizer operations of the ERCO plant had resulted in severe fluoride pollution of the air and toxic effects on crops and farm animals. During the years 1965 to 1967, 58 individual residents in the Port Maitland area were awarded by arbitration compensation, payments amounting to $271,244.00 for livestock and crop damage.

The installation of air pollution control equipment by ERCO decreased the annual average levels of air pollution from 789 ug Fluoride/ 100 cm^2/30 days in 1965 to 518 ug F in 1966 to 261 ug F in 1967 as recorded at 16 air sampling stations in the Port Maitland area. To further reduce fluoride emissions, ERCO did not produce superphosphate fertilizers during the 1968 growing season. The annual average fluoridation rate decreased to 155 ug F in 1968. This cessation in the production of superphosphate fertilizers by ERCO was required in subsequent growing seasons (April 15 - October 15) by a Minister's Order. In 1969 the annual average fluoridation rate was 118 ug F/100 cm^2/30 days.

A number of animal complaints concerning alleged reproductive failures were received in 1970 and 1971. A comprehensive animal reproductive study was conducted on farm properties in the Port Maitland area in 1971 which demonstrated that the cattle reproductive failures were the result of poor herd management and not due to the ingestion of fluoride-contaminated forage. No animal complaints were received in 1972 or subsequent years through 1976.

The Minister's Order was carried out by ERCO until 1973. In 1974, when a shortage of phosphate fertilizers developed, the Minister's Order was relaxed requiring curtailment of fertilizer production only during the period May 15-August 31. Additional air pollution controls installed by new management (IMC) prevented any additional adverse effects in the Port Maitland area.

In 1975, with the installation of additional air pollution controls, the 1968 Minister's Order was revoked permitting year-round production of superphosphate fertilizers. A new Control Order was served IMC specifying that the company would be required to cease operations if the level of fluoride in forage within 3000 meters of the plant exceeded certain allowable limits. At no time during the growing season of 1975 was the Control Order requirements exceeded, as determined by fluoride analysis of forage collected at six Control Order sampling stations. Although there was a slight increase in fluoride levels in native vegetation close to the industry and an increase in the area displaying trace to light injury, no adverse effects occurred on commercial farm properties to the northeast and east.

In 1976, IMC was subjected to the same Control Order as served in 1975. The Control Order requirements again were not exceeded at any time during the growing season of 1976 in which 12 consecutive bi-weekly collections of forage were made at the six sampling stations. There was a slight improvement in levels of fluoride in native vegetation in the area. Only two complaints of

alleged fluoride injury to crops and no animal complaints were received by the Phytotoxicology Section in 1976 from the Port Maitland area. Investigation of the two complaints showed that fluoride levels in the vegetation examined were low and well below toxic levels. Both injury complaints were diagnosed as being caused by agents other than fluorides - disease in one case, and overapplication of pesticides in the other case.

In 1977, unlike 1975 and 1976 when no violations of the Control Order occurred, the first forage sampling in early May 1977 showed high concentrations of fluoride. During a meeting held with IMC officials it was indicated that the source of the emissions was the granulation unit. The company ceased operating its den and granulation unit during most of June and July until the fluoride content of forage in the surrounding area was in compliance with the Control Order. The company then received permission from the West Central region to resume operations, and subsequent testing by the Phytotoxicology Section showed that fluoride levels in forage were in compliance with Control Order requirements.

The following table lists the number of vegetation and animal complaints investigated by the Phytotoxicology Section in the Port Maitland area for the period 1968 to 1977 inclusive.

Year	Complaints	
	Vegetation	Animal
1968	31	4
1969	26	4
1970	11	12
1971	11	14
1972	10	0
1973	5	0
1974	2	0
1975	4	0
1976	2	0
1977	4	1

FIBERGLAS MANUFACTURER

Studies have been conducted annually since 1969 in the vicinity of a fiberglas manufacturer in southern Ontario. Symptoms of injury on vegetation followed the changing pattern of emissions from the fiberglas plant from 1969 through the following years. In 1969, severe fluoride injury was observed on vegetation growing southeast of the source up to a distance of about 150 meters. Light fluoride injury extended southeast for an additional 150 meters. This pattern remained unchanged in 1970. In 1971, despite the reduction in fluoride emissions, the extent of the area in which vegetation injury occurred was observed not to decrease. Instead, symptoms of boron toxicity became more prominent on leaves of native vegetation in addition to typical fluoride injury. In 1972, although fluoride emissions had been virtually eliminated, the area displaying severe vegetation injury did not decrease. Instead, boron injury symptoms predominated, and plant species such as silver, Norway and Manitoba maples, crabapple, green and white ash, buckthorn, forsythia, and honeysuckle showed severe boron injury symptoms. In 1973, boron emissions from the fiberglas plant had been almost totally eliminated and the extent of the area showing boron-type injury on vegetation was reduced. In 1974 and subsequent years despite the virtual absence of fluoride or boron emissions, boron type injury symptoms continued to appear on vegetation close to the source due to uptake of residual soluble fluoride and boron in the soil.

Foliar levels of fluoride and boron in vegetation also reflected the changing pattern of pollution emissions. Average fluoride levels in washed silver maple foliage decreased from 613 ppm (dry weight) in 1969 and 1600 ppm in 1970 to 21 ppm in 1973 and 26 ppm in 1974 at the sampling station closest to the fiberglas plant. Boron contents of the same vegetation rose from 196 ppm in 1969 to 509 ppm in 1972, and decreased to 253 ppm in 1973. Fluoride and boron contents of washed versus not-washed foliage were not significantly different indicating that both fluoride and boron atmospheric emissions had been primarily gaseous, or if particulate, were sufficiently soluble to be readily absorbed into the foliage.

BRICKWORKS

In 1975 and in previous years fluoride effects on vegetation had been reported for a number of brickworks located in southern Ontario. In order to appraise these effects and determine the extent of abatement required at each company special surveys of brick, ceramic, frit and glass manufacturing industries were conducted during the growing seasons of 1976 and 1977. At the request of Regional Managers of Industrial Abatement, 20 brick and related industries in the four southern Regions in Ontario were surveyed. The fluoride assessment surveys were conducted on a similar basis at each industry, which consisted of two visits; the first to detect the presence of visible fluoride injury on vegetation in early summer, and the second in late summer to follow the progress of any injury and to

collect foliar samples for fluoride chemical analysis. Following analyses of field observations and chemical analysis results the 20 surveyed companies were ranked individually in an order of priority within three general groups based on the degree of fluoride injury observed on vegetation and on the levels of fluoride found within foliage of vegetation. The most adverse fluoride effects were found in the vicinity of three of the 20 companies surveyed.

HYDROFLUORIC ACID MANUFACTURER

In addition to conducting fluoride assessment surveys in the vicinity of existing industries, pre-operational surveys are carried out in the vicinity of a major proposed source which has the potential to emit fluorides. Prior to the start-up of a hydrofluoric acid manufacturer in southwestern Ontario a phytotoxicology baseline study was conducted to document the normal background conditions in the area. Vegetation sampling stations were established at 1/2 mile, and then at 1 mile intervals along each of three radii originating from the proposed hydrofluoric acid industry. In addition gladiolus indicator plots established at distances of 100 yards northeast to 12 miles north of the company were examined for injuries and harvested for chemical analysis. Following start-up of the new operations, a post-operational assessment study was conducted with sampling repeated at the same established stations.

Table 1 compares the average fluoride concentrations for all plant species sampled at each vegetation station for the two years of surveillance. It is apparent that the

fluoride levels were normal in vegetation at all stations examined in the pre-operational study, whereas after start-up of the new operation the fluoride levels in vegetation increased dramatically at stations located within a 1 mile radius of the company. The same striking increase was found in the gladiolus indicator plants as shown in Table 2. In addition, whereas no fluoride injury symptoms were observed on native or indicator vegetation before industrial start-up, severe fluoride injury developed on plant species in the study area after start-up. Further there was no significant correlation "before", and a strong significant correlation "after" between fluoride concentrations in vegetation and the rate of fluoridation by lime candle air sampling at nearby stations.

The previous description is an example of one case history where a post-operational study showed adverse effects occurring in an area following industrial start-up. This study was of great assistance to both company and government environmental engineers who proceeded to re-examine the operation's emissions in order to install better control devices where needed.

OIL REFINERY

I'll briefly discuss a recent tree damage episode which was investigated in the vicinity of an oil refinery. In midsummer the Phytotoxicology Section received numerous calls from residents neighboring the oil refinery about the sudden browning of ornamental pine trees on their properties. Both the refinery and the regional Industrial

Abatement staff were not sure of the source or what contaminant was responsible for the damage. The Phytotoxicology Section investigated the complaints and determined that various kinds of trees, particularly pines, had been injured in a three-mile swath leading out in a northeast direction from the refinery. The field observations, based on sensitivity and resistance of various tree species and on the appearance of the symptoms of injury, indicated that hydrogen fluoride was the causal agent. However, the company could not ascertain any source of the hydrogen fluoride or find any record of an accidental release of high concentrations of the gas. Samples of injured and healthy foliage collected in the vicinity of the refinery were processed in the Phytotoxicology laboratory for chemical analysis and histopathology. The laboratory results, based on fluoride levels in the collected foliage and on cellular changes observed microscopically in the injured leaf tissues confirmed that hydrogen fluoride was responsible for the injuries. The pattern of tree damage throughout the area indicated that only the oil refinery could be the source of the gas. Upon receipt of the report of the investigation, the refinery accepted responsibility for the emission, having subsequently found that the incineration of polymer with free hydrofluoric acid was suspect, and agreed to settle all damage claims from neighbouring residents.

ALUMINUM MANUFACTURER

Many of you have probably read or heard through the media about the fluoride problem in the St. Regis Indian

Reserve on Cornwall Island. I would like to conclude with a summation of events that has occurred there with respect to fluoride emissions from the Reynolds aluminum manufacturing plant located on the other side of the St. Lawrence River at Massena, New York.

During the years 1969 to 1971 severe fluoride effects on vegetation were found at the south end of Cornwall Island due to transboundary flow of atmospheric fluorides. On the basis of the Ontario Phytotoxicology findings, an Order was issued by New York State requiring Reynolds Metals to install control equipment to reduce emissions. Abatement measures taken by Reynolds were reflected in pronounced improvements in 1972 in the degree and extent of fluoride contamination on Cornwall Island. However, in subsequent years, although fluctuations in fluoride contamination were documented annually, no real improvement was found to occur since 1972.

In 1976 and 1977 a cooperative Federal-Provincial study was conducted in the Cornwall area in which the Ontario Ministry of the Environment, Environment Canada, Canada Agriculture and Canada National Health and Welfare participated. Investigations were conducted on the status of air quality and the effects on vegetation, animals and human health in the St. Regis Indian Community. The studies showed that fluoride emissions were responsible for causing adverse effects on air quality, vegetation and animals in a small portion at the south end of Cornwall Island, approximately 2 km wide. No adverse effects were detected with respect to human health on the island. The International

Air Pollution Advisory Board held a fact finding hearing at Massena, New York on June 28 and 29, 1977 and heard representations from the government agencies involved, from the industry and from the St. Regis Indian Band. A report of this hearing was provided to the International Joint Commission for any subsequent action.

TABLE 1 - FLUORIDE LEVELS IN VEGETATION AND AIR

Distance and Direction from Source of Air Pollution	Before Industrial Start-Up			After Industrial Start-Up		
	Average Fluoride Concentration in Sampled Vegetation (ppm)	Average Fluoridation Rate in Lime Candle (ugF/100 cm^2/30 days	Severity of* Injury on Vegetation	Average Fluoride Concentration in Sampled Vegetation (ppm)	Average Fluoridation Rate in Lime Candle (ugF/100 cm^2/30 days)	Severity of* Injury on Vegetation
0.5 mi. NE	11	21	0	381	790	3-4
1 mi. NE	11	11	0	54	46	1-2
2 mi. NE	9	18	0	18	52	0
3 mi. NE	13	21	0	14	32	0
0.7 mi. E	7	-	0	45	-	1-2
1.25 mi. E	8	11	0	16	22	0
2 mi. E	10	20	0	19	49	0
3 mi. E	9	16	0	11	22	0
0.5 mi. SE	12	-	0	193	-	2-3
1.1 mi. SE	10	22	0	34	141	1
2 mi. SE	9	16	0	22	47	0
3 mi. SE	11	15	0	17	26	0

Correlation Coefficients Fluoride in Vegetation and Air: r = 0.40 (not significant); r = 0.99** (significant at 1% level)

* Severity Rating 0 = none, 1 = trace, 2 = slight, 3 = moderate, 4 = severe

TABLE 2

COMPARISONS BETWEEN THE PERCENT LEAF INJURY AND FLUORIDE LEVELS FOR UPPER AND LOWER HALVES OF OLDER AND YOUNGER LEAVES IN SNOW PRINCESS GLADIOLUS PLANTS

Gladiolus Plot Location with Respect to Source	Chemical Analysis Results - Fluoride (ppm) Average of 20 Gladioli per Plot				Percent Leaf Injury
	Upper half of older leaves	Lower half of older leaves	Upper half of younger leaves	Lower half of younger leaves	
			Before Industrial Start-Up		
100 yd. Northeast	8.0	6.0	6.0	4.0	1.75
12 miles North	7.0	2.0	7.0	0	7.70
			After Industrial Start-Up		
100 yds. Northeast	1327.5	1127.5	1377.5	1002.5	100.0
12 miles North	4.0	3.0	4.0	3.0	2.5

HEALTH ASPECTS OF COKE OVEN EMISSIONS

By
Dr. R.H. Martin,
Corporate Medical Director
Dominion Foundries & Steel, Limited
Hamilton, Ontario

Dominion Foundries and Steel, Limited (DOFASCO), is Canada's second largest integrated steel making operation with annual sales approaching one billion dollars. The company employs about 11,000 persons and the main plant is located in Hamilton, Ontario.

As part of the steel making process, coke is produced in coke ovens by distilling pulverized coal to drive off the volatile tars and gases. The coke, in turn, is used in blast furnaces to reduce pelletized iron ore to liquid iron.

During the coking process, tars and gases are released into the atmosphere. The tar vapours solidify in the relatively cold air to form tar droplets. A number of potentially carcinogenic aromatic hydrocarbons including benzo (a) pyrene or BAP are present in these coke oven emissions. The fume is very similar to cigarette smoke.

Work carried out by Dr. William Lloyd during the late 1960's has shown that U.S. coke oven workers with more than five years experience may be 2.5 times more likely to develop lung cancer than other steel plant workers. Those coke oven workers who spent their time on the higher exposure topside areas may be ten times more likely to develop lung cancer. To keep this risk in perspective, cigarette smokers have 15 to 30 times the risk of non-smokers. At Dofasco, 51% of our employees smoke. This is about the same rate as the general population. Among our coke oven employees, however, 65% are smokers. The rate is even higher among those coke oven workers less than 45 years of age.

We first became aware of the apparent excess lung cancer risk through unpublished communications with Dr. Lloyd in 1969. At that time we initiated a voluntary respirator program for our own employees and expanded our medical surveillance. Respirators have since become mandatory for all coke battery personnel. Regular industrial hygiene exposure monitoring has been carried out since 1971.

The current Ontario Ministry of Labour exposure standard (TLV) for coke oven emissions is 0.2 milligrams of benzene soluble material or tar per cubic meter of air. No coke plant in the world can meet this limit for all employees without using respirators.

All our coke plant employees were made aware of the hazard and measures to control exposure from the beginning through a series of lectures by the medical and coke plant departments. In 1976 we put together an audio-visual presentation to bring everyone involved up to date on the situation.

I would like to show you this fifteen minute educational video-tape now. When it is over, I will discuss the measures we have taken since 1976 to continue to reduce employee exposures.

VIDEOTAPE TRANSCRIPT

> Hello, I'm Dr. Martin. As Director of Dofasco's Medical Department, one of my primary concerns is Industrial Hygiene. This is the branch of medicine that relates employee's health to specific conditions

of their jobs. Now, our health conservation program for coke oven workers is patterned after a report on studies conducted by a Dr. Lloyd in the United States. The studies revealed a statistical link between workers on the topside of coke oven batteries and lung cancer. They noted that such workers with more than five years of exposure, have a ten times greater risk of contracting lung cancer than the normal. Those working on the battery side for a similar period of time, have a risk two and one half times greater. Other similar studies on smoking, coronary heart disease and even women taking the pill, demonstrate the same kind of statistical risks. Our job is to determine and identify the areas where we can take preventive measures to reduce these risks to your health.

What is it about coke oven work that does this damage? Many believe the tar substances in battery smoke, substances quite similar to those in cigarettes, are the culprits. Now, what is the safe level of tar? The Ontario Ministry of Health (now Labour)

guidelines describes it as under 0.2 milligrams of tar per cubic meter of air. There is only one trouble with this level. Existing environmental control techniques in any of the steel plants in North America, simply can't give us air that clean. So, Dofasco has designed a three phase program in order to meet those guidelines and try to make the coke ovens a healthier place to work.

"Phase One" is all about good coke oven practices. Let's look at some of the things you can do to make the coke ovens a safer place. The best defense against coke oven emissions is to prevent the escape of smoke. This requires the cooperation of everyone on the coke oven crew to keep the doors clean and tight, to seal the lids properly after charging and to charge the ovens in the prescribed manner. The standpipes and goosenecks must be cleaned before each charge so that the gases have a free passage to the collector main. Cleaning and checking the charging steam noggles regularly is essential so that we can get enough suction to charge evenly.

This same sort of house cleaning applies to the top of the battery as well. It must be kept clear of coal. Coal smoking topside gives off the same emissions as coal being coked in the oven.

The pusher man and door machine operator must spot the machines carefully to avoid damage to the knife edges. The patchers must maintain the jambs and regenerator so that the ends of the ovens are properly heated and the heaters must control the gas and air volumes to ensure that the coal is evenly coked out. Providing suitable machinery for the job, and setting standard practices for keeping emissions to a minimum is management's task. With everyone doing his job honestly and carefully, emissions will be kept to a minimum and the coke ovens will be a cleaner, more pleasant place to work.

Since technology doesn't exist to completely eliminate harmful coke oven emissions, "Phase Two", consists of on-the-job protection.

Dofasco provides respirators to filter the air you breathe, bringing it within safe standards. We also provide barrier cream to coke oven workers that, when applied to the hands and face, retains natural skin oils and helps prevent dermatitis and skin cancer. We've had a lot of questions on just how effective a respirator is. The respirators we give you were not chosen at random. They were chosen specifically because they provide high protection and comfort. They filter out the solids in the atmosphere around the coke oven battery so that the air you breathe is much cleaner. If you are skeptical, just compare a new filter with one that has been used for an eight hour shift. The important thing is that the respirator must be worn whenever you are working on the battery, even for a short period of time. When worn, they will clean the air you breathe, bringing it within the Ontario government's guidelines. But we are still on the lookout for better respirators and we'll be trying new ones as they become available.

In the meantime, we like to keep records on how well our control practices are working. Monitoring the exposures we have been talking about is the job of our Industrial Hygiene Department. We regularly take air samples using small battery operated pumps, clipped on to a man's belt. Connected to this is a filter that attaches to his collar so that the apparatus breathes the same air as the man during a full shift. We then take the filter back to the laboratory for analysis. The results of the lab analysis tell us the exposure level for each man.

"Phase Three" is the medical and biological program. A pre-employment and yearly medical examination is done on each employee. This ensures that only people in perfect health are assigned to the coke oven area. Special attention is paid to the chest and skin. Your medical history, complete with items like smoking habits, hereditary background with respect to cancer or history of previous respiratory problems is kept in our files.

Yearly chest X-rays are taken to help us identify hidden or dormant problems that could be reactivated with exposure to the coke oven atmosphere. Clearly a man who has had bronchitis or even a mild form of tuberculosis whose chest X-ray showed increasing evidence of scarring would have to be carefully considered before being allowed to enter the coke oven environment. These procedures have been done for many years on all Dofasco employees, so this is nothing new.

In a new screening program of pulmonary function testing, we use a machine called a spirometer which prints a graph when a subject blows into a machine, giving an indication of abnormalities of lung function. It can help us detect previous problems such as bronchitis and emphysema and in certain circumstances it can give indication of future problems.

To further reduce the risk to health, we also do a cytology test or sputum analysis on all battery personnel.

We offer all coke oven personnel, opportunities during the medical examination for counselling on all health aspects of their job.

So, this is what our Coke Oven Health Conservation Program is all about. Not so much in what we do but in what you do to help yourself. In the meantime, we will do our part to see that everything else that has to be done medically and is technically practical, will be done.

We are currently in the process of updating the videotape. As many of you may know, the Ontario Ministry of Labour, Occupational Health Branch, rather than the Ministry of Health, currently administers occupational health standards.

Since 1976, a number of measures have been undertaken to further reduce employee exposure.

At our Number 1 Coke Plant, a cokeside shed has been installed. The shed covers the length of the battery and was designed to collect the pushing emissions from 105 ovens. Two fans and two

wet electrostatic precipitators collect 150,000 cubic feet of air per minute. We were initially concerned that employees working under the shed would be exposed to even higher levels of emissions. Careful use of baffles, however, has eliminated this problem.

Since 1976, we have also completed a program to air-condition all "clean-rooms" and larry car, pusher machine, quench car and door machine cabs. These are not standard industrial air-conditioning units. They contain roughing, and high efficiency filters in series with activated charcoal and potassium permanganate to remove vapours and gases.

The following three graphs show the reduction in exposure attained over the last five years. Door cleaners typically have the highest exposures. After installation of the shed, this decreased by about 30%. Lidmen who traditionally have the second highest exposure, show a reduction of about 70%. This is due both to the effect of the shed and the use of clean rooms. The door machine operator's exposure has dropped about 90% since the installation of controls.

As you can see, even though dramatic reductions have been achieved, we still cannot meet the Ministry of Labour standard of 0.2 mg/m^3 for the jobs with the highest exposure. The mandatory use of respirators is still required. The "Dustfoe 66" quartermask currently in use was selected after great deliberation and has proven very successful.

We have continued to look for even better respirators, however. The last unit to be evaluated was the Racal Airstream AH-1. This unit is a combination hard hat-face shield-filter that has a small blower powered by a belt mounted battery pack. Air is drawn in at the back of the head, through roughing and high efficiency filters and delivered to the breathing zone of the worker. A slight positive pressure keeps dirt out.

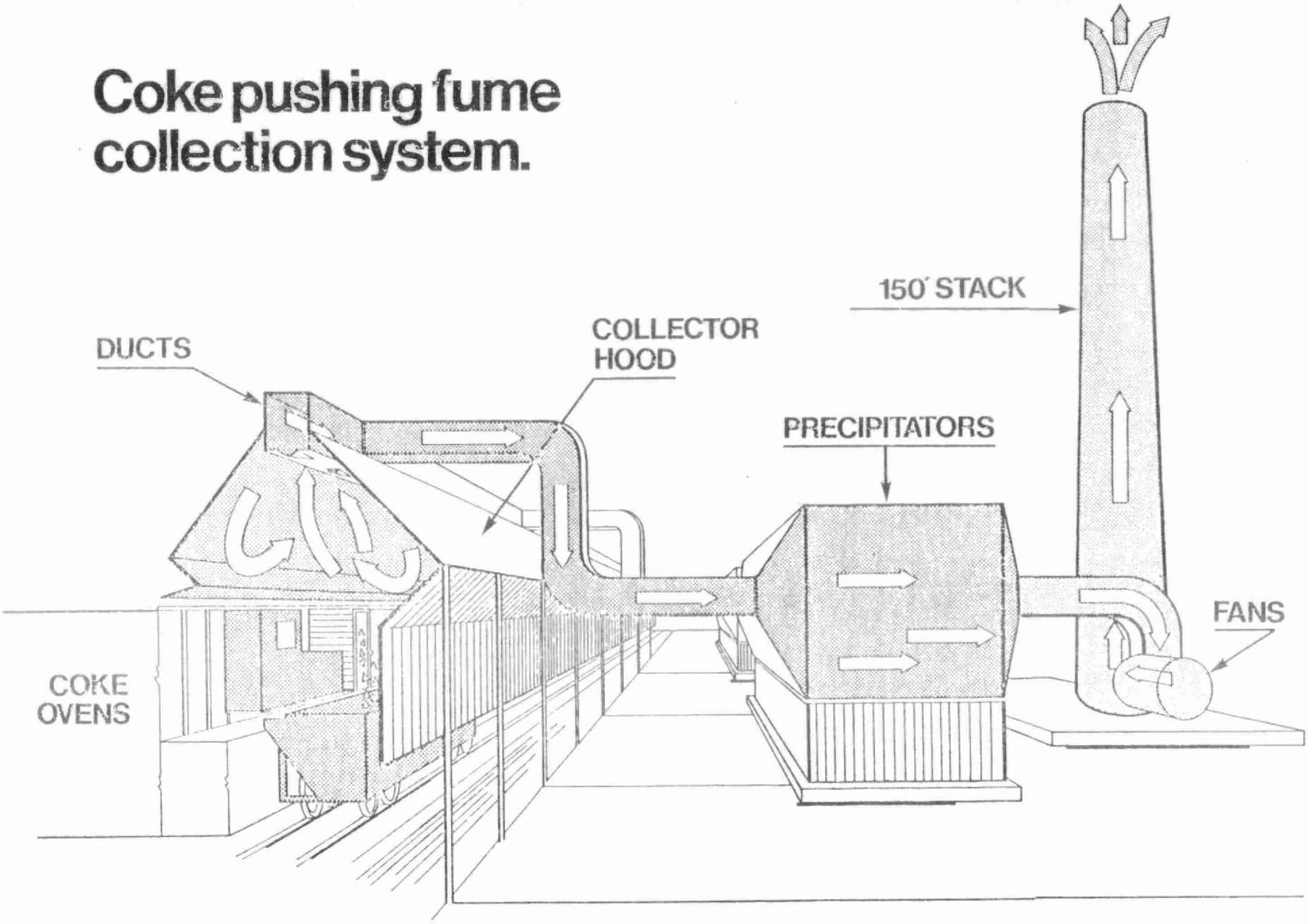
The principle of this unit is excellent. Currently, however, it is not practical for use in coke oven environments. Most problems with the units are related to the extremes of temperature normally encountered on coke batteries and to the high maintenance requirements. We are continuing to evaluate updated versions of the unit.

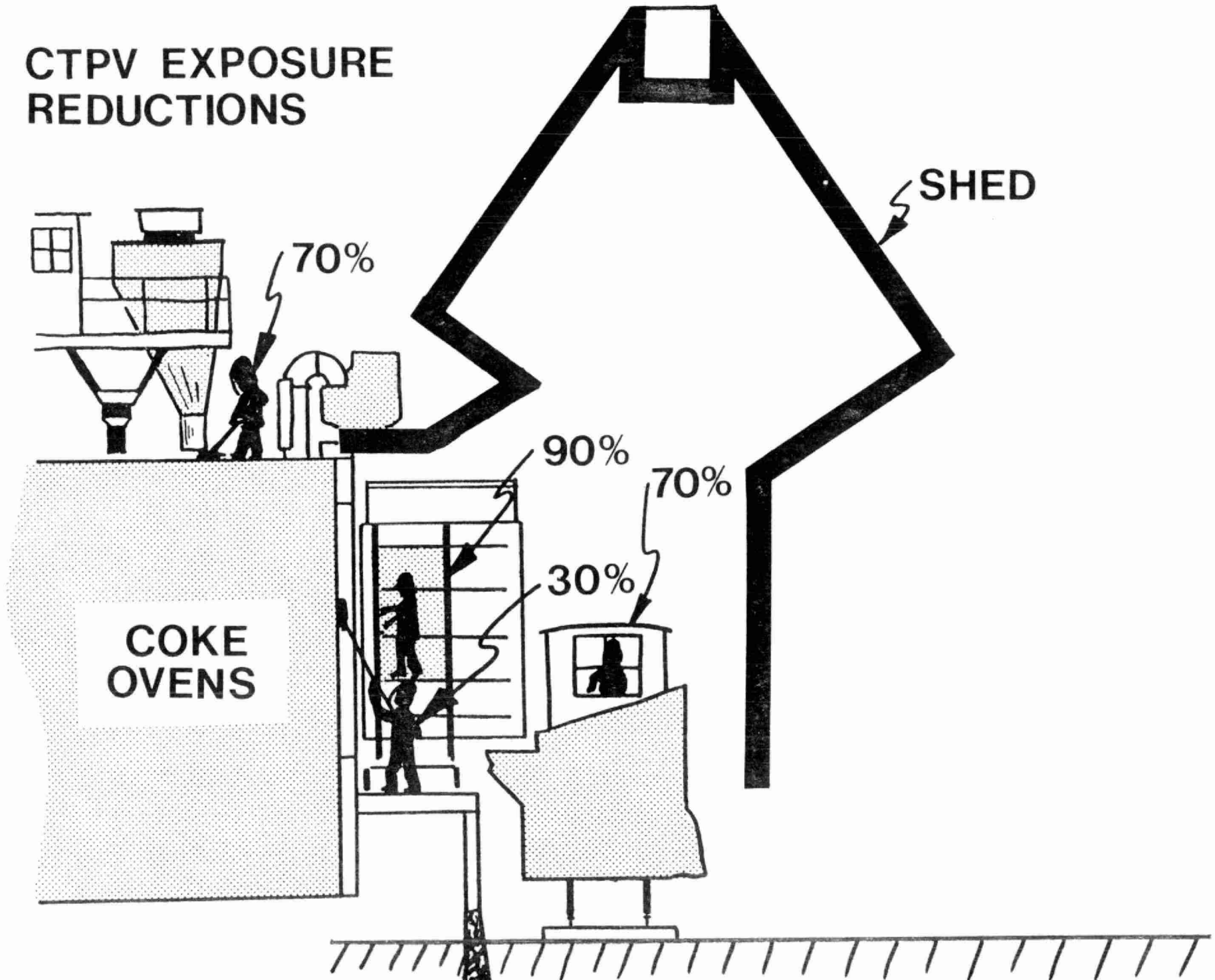
This summer, we will start up a new battery of 6 meter high ovens. The mechanization of battery functions has been maximized to reduce the number of men exposed. A Minister-Stein-Dofasco travelling hood will be used to collect pushing emissions. Again all machine cabs will be supplied with filtered, temperature controlled air. Many operations normally done outside by lidmen and door cleaners will be done hydraulically by operators located in clean rooms. Individual hoods will be installed over all doors to collect leakage during the coking cycle.

We expect personnel exposures on the new battery to approach 0.2 mg/m^3 and look forward to start-up.

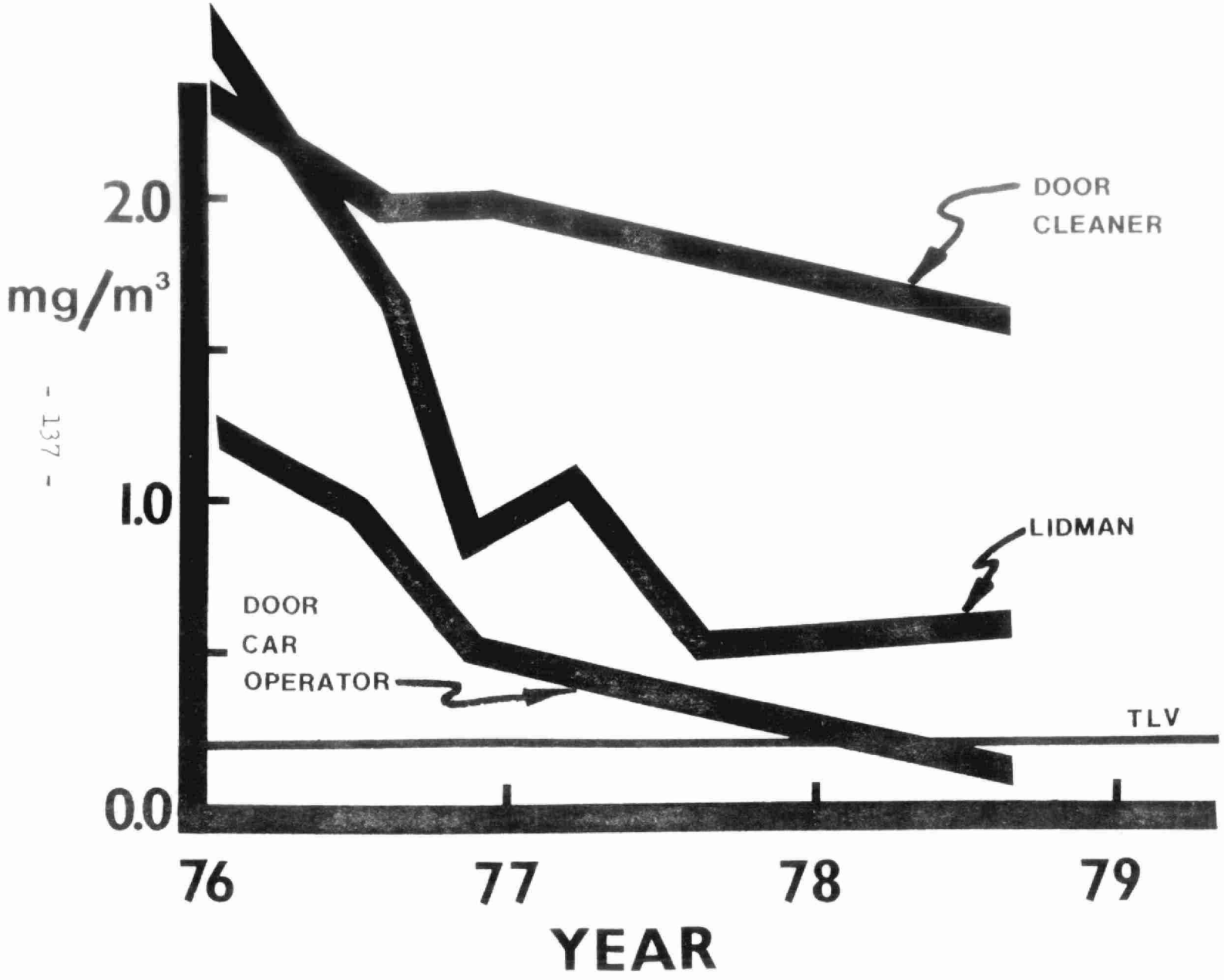
I have outlined steps that we have undertaken to solve a very difficult but very important occupational health problem. We have come a long way in reducing the risk but are still working to reduce it even further.

Coke pushing fume collection system.




CTPV EXPOSURE REDUCTIONS
SHED
70%
90%
70%
30%
COKE OVENS

NO.1 COKE PLANT
CTPV EXPOSURES



EVALUATION OF ODOUR EMISSIONS FROM PAINT BAKE OVENS AT THE GENERAL MOTORS SCARBOROUGH VAN PLANT AND OSHAWA TRUCK PLANT

BY:

WILLIAM HOCKETT

CENTRAL PLANT ENGINEERING
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OSHAWA, ONT.

AIR QUALITY IS OF MAJOR CONCERN TO ALL OF US. WE CAN NOT ALLOW OUR AIR QUALITY TO DETERIORATE. TODAY I AM GOING TO RELATE TO YOU HOW GENERAL MOTORS OF CANADA REACTED TO AN ENVIRONMENTAL CONCERN AT ITS SCARBOROUGH VAN MANUFACTURING PLANT.

IN THE FALL OF 1976, THE MINISTRY OF THE ENVIRONMENT ADVISED GENERAL MOTORS OF A POSSIBLE PROBLEM AT THE SCARBOROUGH VAN PLANT INVOLVING ODOUR EMISSIONS FROM THE BAKE OVEN USED TO CURE THE PRIME UNDERCOAT. WE WERE INFORMED THAT THE MINISTRY OF THE ENVIRONMENT HAD RECEIVED COMPLAINTS ABOUT DISCOMFORTING ODOURS FROM THE NEIGHBOURHOOD SURROUNDING THE VAN PLANT. TO EVALUATE THE SEVERITY OF THE PROBLEM GENERAL MOTORS OBTAINED ASSISTANCE FROM THE GENERAL MOTORS TECHNICAL CENTRE IN WARREN, MICHIGAN. THE RESEARCH CORPORATION OF NEW ENGLAND WAS ENGAGED BY GENERAL MOTORS TO DETERMINE THE EXISTING INFLUENCE OF THE PRIMER BAKE OVEN EMISSIONS ON THE COMMUNITY AMBIENT AIR QUALITY. ODOUR TESTS SHOWED THAT THE PRIMER BAKE OVEN EMISSIONS WERE THE MOST PREDOMINATE ODOUR SOURCES, AND COULD BE DETECTED AT GROUND LEVEL DOWNWIND FROM THE OVEN.

THE RESEARCH CORPORATION MADE A MODEL OF THE BAKE OVEN AND ESTIMATED THE COMMUNITY ODOUR IMPACT IF GENERAL MOTORS CONVERTED TO A PROPOSED NEW PRIME PAINT SYSTEM. THE RESULTS OF THE SIMULATION

WAS NO ODOUR SHOULD BE DETECTED BEYOND THE PLANT PROPERTY LINE IF THE SCARBOROUGH PLANT CONVERTED THE PRIME UNDERCOATING FROM ANIONIC ELECTRODEPOSITION TO CATIONIC ELECTRODEPOSITION.

AS A MEMBER OF THE ENVIRONMENTAL ENGINEERING STAFF AT GENERAL MOTORS, I WAS PART OF A TEAM ASSIGNED TO EVALUATE THE EFFECTIVENESS OF A NEW PRIME UNDERCOATING SYSTEM IN THE REDUCTION OF ODOURS. GENERAL MOTORS HAS COINED THE NAME ELPO FOR THE PROCESS OF ELECTROPLATING PRIME PAINT. IT IS DERIVED FROM THE PHRASE ELECTRODEPOSITION OF POLYMERS.

AT THE VAN PLANT, GENERAL MOTORS MODIFIED THE EXISTING PRIME UNDERCOATING SYSTEM TO USE A CATIONIC ELPO PRIMER SYSTEM. THE PRIMARY OBJECTIVE WAS TO INCREASE THE VAN CORROSION PROTECTION. A VERY DESIRABLE BY-PRODUCT, IN ADDITION, WAS THAT THE NEW CATIONIC SYSTEM PRODUCED SIGNIFICANTLY LESS ODOUR EMISSIONS FROM THE OVEN STACKS.

THE AIR RESOURCES BRANCH OF THE MINISTRY OF THE ENVIRONMENT IN CO-OPERATION WITH GENERAL MOTORS ENGAGED THE ONTARIO RESEARCH FOUNDATION TO PERFORM EMISSION TESTS BEFORE AND AFTER THE PROCESS CHANGE.

THIS REPORT WILL DISCUSS THE PRIME PAINT PROCESS, THE PROCESS MODIFICATION AT THE VAN PLANT, THE DATA OBTAINED FROM THE STACK TESTING AT THE SCARBOROUGH VAN PLANT AND THE STACK SAMPLING PROGRAM SUBSEQUENTLY CONDUCTED BY THE MINISTRY OF THE ENVIRONMENT AT THE OSHAWA TRUCK PLANT.

SCARBOROUGH PRIME PAINT PROCESS

To get a feel for how the odour reduction was accomplished, the process must be discussed.

The control of odour emissions can be accomplished in several ways. They can be summarized as follows:

1. Incineration
2. Absorption
3. Dispersion
4. Change of Process

Due to the low concentration of the organic compounds and the high volume of exhaust gases the first three control methods were not considered feasible at the Scarborough Van Plant.

The optimum control procedure is to minimize the odour emissions through process modification, such as formulating new coatings containing lower quantities of volatile material, which are not easily oxidized.

The problem of odours around the Scarborough Plant was minimized by a process modification. In this section of the report I am going to cover the process operation and how it has changed.

THE PROCESS BEFORE MODIFICATION CAN BE DESCRIBED AS FOLLOWS.

THE PRIME UNDERCOATING FOR VANS IS APPLIED BY PASSING THE VEHICLE BODIES THROUGH A TANK OF PAINT. AS THE VEHICLES ENTER THE TANK ON AN OVERHEAD CONVEYOR, THEY ATTAIN AN ANODIC OR POSITIVE CHARGE.

THE TANK SERVES AS THE CATHODE AND THE ELECTRICAL CURRENT APPLIED TO THE WATER BASE SOLUTION CAUSES THE PAINT PARTICLES TO MIGRATE TO THE POSITIVELY CHARGED VAN, WHERE THEY LEAVE THE SOLUTION AND FORM A THIN, EVEN COATING ON THE VAN SURFACE. EACH VAN THEN PASSES THROUGH A MULTIZONE OVEN FOR CURING AND BAKING OF THE PAINT.

THE FIRST PHASE OF THE SAMPLING PROGRAM TOOK PLACE AT THIS STAGE.

THE MODIFICATION MADE TO THE PROCESS DURING THE CHANGE OVER INVOLVED A COMPLETE CHANGE OF PAINT WITH DIFFERENT SOLID AND SOLVENT COMPOSITION AND A REVERSAL OF CHARGES TO THE VEHICLE BODY AND THE TANK. THE SECOND PHASE OF SAMPLING OCCURED AT THIS STAGE.

IN SUMMARY, GENERAL MOTORS UNDERWENT A COMPLETE PROCESS CHANGE FROM AN ANIONIC ELPO TO CATIONIC ELPO WITH THE RESULTS A SIGNIFICANT ODOUR REDUCTION FROM THE ELPO BAKE OVEN.

THE USE OF THE NEW COATING PROCESS REDUCES ODOUR EMISSIONS FROM THE OVEN, BASED ON ODOUR EMISSION DATA BY APPROXIMATELY FIFTY PERCENT. THIS CONCLUSION IS DRAWN FROM THE EVALUATIONS AND MEASUREMENTS MADE AND DATA COLLECTED DURING AN EMISSION STUDY CONDUCTED BY ONTARIO RESEARCH FOUNDATION.

THE SAMPLING AND ANALYTICAL PROCEDURES USED BY O.R.F. WERE APPROVED BY THE AIR RESOURCES BRANCH OF THE MINISTRY OF THE ENVIRONMENT. A BRIEF SUMMARY OF THE STEPS USED TO OBTAIN THE EMISSION SAMPLES WILL BE GIVEN IN THIS NEXT SECTION OF THE REPORT.

STACK TESTING PROGRAM AT THE SCARBOROUGH VAN PLANT

THE SAMPLING PROGRAM FOR EACH PHASE OF TESTING SPECIFIED THE DETERMINATION OF THE FOLLOWING:

1. ODOUR THRESHOLD LEVELS
   - A) AT STACK TEMPERATURES (WITH PREDILUTION)
   - B) AT AMBIENT TEMPERATURES (WITHOUT PREDILUTION)
2. TOTAL HYDROCARBONS IN THE GASEOUS FORM
   - A) AT STACK TEMPERATURE
   - B) AT AMBIENT TEMPERATURES
3. CONCENTRATION OF ORGANIC ACIDS IN EACH STACK
4. EMISSION CONCENTRATIONS OF AEROSOLS AT THE STACK TEMPERATURES AND ALDEHYDES, EXPRESSED AS FORMALDEHYDE

THE EXHAUST GASES FROM THE VARIOUS OVEN ZONES ARE VENTED TO ATMOSPHERE THROUGH STACKS, ABOUT THIRTY FEET ABOVE ROOF LEVEL. ALL EMISSION SAMPLES WERE COLLECTED FROM THE ROOF THROUGH SAMPLING PORTS PROVIDED BY GENERAL MOTORS AT AGREED LOCATIONS, IN EACH STACK. THE SAMPLE WAS WITHDRAWN FROM FOUR SAMPLING POINTS IN EACH STACK FOR A TOTAL SAMPLING TIME OF 20 MINUTES, 5 MINUTES PER POINT. THE TOTAL VOLUME OF GAS SAMPLED WAS SUFFICIENT TO CARRY OUT AN EIGHT MEMBER ODOUR PANEL EVALUATION.

THIS SLIDE SHOWS THE SAMPLING SITE ON THE OVEN ROOF.

1. ODOUR EVALUATION

EMISSION SAMPLES WERE COLLECTED USING A PLEXIGLASS SAMPLING LUNG. THE SAMPLE IS DRAWN INTO THE PLASTIC BAG BY THE NEGATIVE PRESSURE IN THE DRUM. WHEN THE SAMPLE IS OBTAINED, THE BAG IS TRANSPORTED BACK TO THE LABORATORY.

IN THE ODOUR TEST FACILITY THE BAGS WERE EVALUATED BY AN EIGHT MEMBER ODOUR PANEL.

THE SAMPLE BAG IS PRESSURIZED IN A PRESSURE VESSEL AND THE SAMPLE FLOWS THROUGH ONE OF TWO FLOWMETERS AT A PRE-DETERMINED RATE. THE SAMPLE IS DILUTED WITH ODOUR FREE AIR PRIOR TO REACHING ONE OF TWO 'SNIFF PORTS' IN EACH CUBICLE FOR EVALUATION. ODOUR FREE AIR IS PASSED THROUGH THE OTHER 'SNIFF-PORT'. THE PANELIST MUST SMELL BOTH AND MUST DECIDE

1. ODOUR EVALUATION (CONT'D)

WHICH IS THE ODOUROUS PORT. ODOUR EVALUATIONS ARE MADE FOR A SERIES OF DILUTIONS BY EACH PANELIST AND THEIR RESPONSE TO AN ODOUR FROM EITHER PORT IS RECORDED ELECTRONICALLY. THE DILUTION LEVEL AT WHICH THE PANELIST FIRST MADE THE CORRECT CHOICE AND CONTINUED TO BE CORRECT AT TWO HIGHER CONCENTRATION LEVELS IS TAKEN TO BE THE PANELIST'S DILUTION THRESHOLD. THE PANEL OPERATOR RECORDS THE RESPONSES FOR EACH DILUTION AND PLOTS THE PERCENTAGE RESPONSE AGAINST DILUTION NUMBER TO DETERMINE THE ODOUR THRESHOLD VALUE FOR EACH SAMPLE.

IN SUMMARY, EMISSION SAMPLES FROM THE ELPO PAINT BAKING OVEN WERE COLLECTED BEFORE AND AFTER THE PROCESS CHANGE. ALL SAMPLES WERE EVALUATED BY AN ODOUR PANEL TO OBTAIN THRESHOLD VALUES. THE PROCESS CHANGE HAS RESULTED IN A REDUCTION OF ODOUR THRESHOLD VALUES FOR MOST OF THE OVEN STACK EMISSION. BASED ON THE TOTAL ODOUR EMISSION RATE FROM THE OVEN, A REDUCTION OF APPROXIMATELY 50% WAS OBTAINED.

THE NUMBER ONE STACK INCREASED, BUT ALL OTHER STACKS DECREASED. THIS CHARACTERISTIC IS CAUSED BY PAINT FORMULATION.

2. TOTAL HYDROCARBONS

THE TOTAL HYDROCARBON CONCENTRATIONS WERE DETERMINED DIRECTLY IN THE STACK GAS OR IN COLLECTED BAG SAMPLES USING AN I.P.M. RATFISCH MODEL RS5 CONTINUOUS HYDROCARBON ANALYZER, EQUIPPED WITH A FLAME IONIZATION DETECTOR.

2. TOTAL HYDROCARBONS (CONT'D)

AFTER THE PROCESS CHANGE, THE HYDROCARBON LEVELS HAVE INCREASED, THEREFORE, THERE IS NO CORRELATION BETWEEN HYDROCARBON VALUES AND ODOUR THRESHOLD VALUES SINCE THE LATTER DECREASED FOLLOWING PROCESS MODIFICATION. HYDROCARBON CONCENTRATIONS FROM THE ELPO PROCESS ARE INSIGNIFICANT WHEN COMPARED TO CONVENTIONAL PRIME PAINTING.

3. ORGANIC ACIDS

THE STACK SAMPLING EQUIPMENT USED TO COLLECT SAMPLES FOR THE ANALYSIS OF ORGANIC ACIDS WAS THE ENVIRONMENTAL PROTECTION AGENCY APPROVED SAMPLING TRAIN. CONCENTRATIONS OF ORGANIC ACIDS IN THE OVEN STACK EMISSIONS WERE DETERMINED BY BUBBLING THE STACK GAS THROUGH DILUTE CAUSTIC SOLUTION, FOLLOWED BY ACIDIFICATION AND ETHER EXTRACTION OF THE FREE ORGANIC ACIDS.

FOLLOWING PROCESS MODIFICATION, EMISSION CONCENTRATIONS OF ORGANIC ACID HAVE DECREASED AN AVERAGE OF 58 PERCENT. THIS OVERALL DECREASE IS SIMILAR TO THAT FOR ODOUR THRESHOLD, BUT THERE IS NO OBVIOUS CORRELATION OF ODOUR THRESHOLD VALUE WITH ACID CONCENTRATION.

NOTE DECREASE FROM ALL STACKS

4. ALDEHYDES AND AEROSOL DETERMINATION

AN EPA SAMPLING TRAIN USED TO COLLECT ORGANIC ACID WAS ALSO USED TO COLLECT SAMPLES FOR ANALYSIS OF ALDEHYDES. IN THE TESTS TO DETERMINE ALDEHYDE CONCENTRATION, FILTERS WERE

4. ALDEHYDES AND AEROSOL DETERMINATION (CONT'D)

USED IN THE SAMPLING TRAIN TO COLLECT PARTICULATE MATERIAL AND/OR ORGANIC AEROSOL.

CONCENTRATIONS AND EMISSION RATES OBTAINED FOR BOTH PHASES OF THE PROGRAMME ARE VERY LOW FOR ALL STACKS, AND THERE IS NO SIGNIFICANT CHANGE IN EMISSION RATES FOLLOWING PROCESS MODIFICATION.

TO SUM UP THE SAMPLING PROGRAMME AT THE SCARBOROUGH VAN PLANT, THE FOLLOWING CONCLUSIONS ARE DRAWN:

1. THE USE OF A NEW CATHODIC ELECTRODEPOSITION COATING REDUCES ODOUROUS EMISSIONS FROM THE OVEN, BY APPROXIMATELY FIFTY PERCENT

2. FOR THE NEW PROCESS OPERATION, THE ODOUR INTENSITIES OF EMISSIONS FROM EACH OVEN STACK ARE SIMILAR.

3. THERE IS NO CORRELATION OF ODOUR THRESHOLD LEVELS WITH TOTAL HYDROCARBON VALUES.

4. A POSSIBLE CORRELATION BETWEEN ODOUR THRESHOLD AND A COMBINATION OF ORGANIC ACID AND ALDEHYDE CONCENTRATIONS EXITS.

OSHAWA TRUCK PLANT STACK SAMPLING PROGRAM

We will now focus our attention on the Oshawa Truck Plant.

The objective of the Truck Plant stack sampling programme was to compare the findings of two independent stack sampling teams, sampling at different plants with similar operations. The Air Resources Branch of the Ministry of the Environment conducted an emission survey of the number one ELPO paint bake oven at the Oshawa Truck Plant.

The painting operation at the Oshawa Truck Plant includes an anionic ELPO prime undercoating system for the truck cabs.

The process and paint formulation at the Oshawa Truck Plant is similar to the anionic ELPO used at the Scarborough Van Plant before the change was made to cationic ELPO.

The truck cabs are plated by being immersed in a dip tank filled with a mixture of paint solids and water, and applying an electric current between the immersed cab and the paint cells. The cabs then are baked in a three zone oven. The exhaust gases from the oven zones are vented to atmosphere through three stacks and one reflow exhaust stack. All samples were collected from the top of the oven roof at least six stack diameters downstream from the exhaust fans through sampling ports provided by General Motors at agreed locations. Note the sampling platforms in the slide.

This slide shows the layout of the oven.

OSHAWA TRUCK PLANT STACK SAMPLING PROGRAM (CONT'D)

THE SAMPLING AND ANALYTICAL PROCEDURES USED BY THE MINISTRY OF THE ENVIRONMENT TO SAMPLE THE TRUCK PLANT OVEN EXHAUST WERE SIMILAR TO THE PROCEDURES USED BY THE ONTARIO RESEARCH FOUNDATION AT THE SCARBOROUGH VAN PLANT.

HERE ARE SEVERAL SLIDES OF THE MINISTRY OF THE ENVIRONMENT DURING THE SAMPLING PROGRAM.

THE SAMPLING PROGRAM SPECIFIED THE DETERMINATION OF THE FOLLOWING:

1. ODOUR THRESHOLD LEVELS
2. TOTAL HYDROCARBONS
3. ORGANIC ACID
4. ALDEHYDE

THE RESULTS WERE AS FOLLOW:

1. ODOUR THRESHOLD LEVELS

ALL SAMPLES WERE EVALUATED BY AN ODOUR PANEL MADE UP OF THE MINISTRY OF THE ENVIRONMENT EMPLOYEES. THE ODOUR THRESHOLD VALUE OBTAINED AT THE OSHAWA TRUCK PLANT USING ANIONIC ELPO WAS SIMILAR TO THE ODOUR THRESHOLD VALUE DETERMINED AT THE SCARBOROUGH VAN PLANT USING ANIONIC ELPO. THE ODOUR EMISSION RATE FROM THE OVEN WAS SLIGHTLY HIGHER AT THE SCARBOROUGH PLANT, BECAUSE OF THE LARGER SURFACE AREA OF THE VAN BODY COMPARED TO THE TRUCK CAB.

THERE IS NO CORRELATION BETWEEN ODOUR THRESHOLD VALUES AND HYDROCARBON, ORGANIC ACID, AND ALDEHYDE EMISSION AT THE OSHAWA TRUCK PLANT.

2. TOTAL HYDROCARBONS

THE HYDROCARBON CONCENTRATIONS ARE SIMILAR AT BOTH OSHAWA AND SCARBOROUGH USING THE ANIONIC ELPO PRIME PAINTING.

3. ORGANIC ACID CONCENTRATIONS ARE HIGHER IN THE SCARBOROUGH VAN PLANT THAN IN THE OSHAWA PLANT. THE DIFFERENCE IS A 99.3 P.P.M. AVERAGE COMPARED TO 308 P.P.M. AVERAGE FOR ALL EXHAUST STACKS IN THE OVEN.

4. THE ALDEHYDE EMISSIONS ARE SIMILAR FOR THE TWO PLANTS.

TO SUMMARIZE: USING THE SAME SAMPLING AND ANALYTICAL PROCEDURES AT BOTH GENERAL MOTORS PLANTS, THE RESULTS ARE COMPARABLE. THIS INDICATES THE PROCESSES AND EQUIPMENT AT BOTH PLANTS USING ANIONIC ELECTRODEPOSITION COATING HAVE SIMILAR ODOUR EMISSION CHARACTERISTICS.

CONCLUSION

IN CONCLUSION, EMISSION SAMPLES FROM AN ELPO PAINT BAKING OVEN, AT THE GENERAL MOTORS PLANT IN SCARBOROUGH, ONTARIO WERE COLLECTED BEFORE AND AFTER A PROCESS CHANGE TO UTILIZE A NEW COATING. ALL SAMPLES WERE EVALUATED BY AN ODOUR PANEL TO OBTAIN ODOUR THRESHOLD VALUES AND ANALYZED TO DETERMINE CONCENTRATIONS OF TOTAL HYDROCARBONS, ALDEHYDE, ORGANIC ACIDS AND PARTICULATE MATERIAL. THE CONCLUDING POINTS ARE AS FOLLOWS:

CONCLUSION (CONT'D)

1. THE PROCESS CHANGE HAS RESULTED IN A REDUCTION OF ODOUR THRESHOLD VALUE FOR MOST OF THE OVEN STACK EMISSIONS BY APPROXIMATELY FIFTY PERCENT.

2. THERE IS NO CORRELATION OF ODOUR THRESHOLD LEVELS WITH TOTAL HYDROCARBON VALUES.

3. A POSSIBLE CORRELATION EXISTS BETWEEN ODOUR THRESHOLD VALUES AND A COMBINATION OF ORGANIC AND ALDEHYDE CONCENTRATIONS, BECAUSE BOTH DECREASED AFTER THE PROCESS CHANGE.

4. THE RESULTS FROM THE FIRST PHASE OF SAMPLING AT THE SCARBOROUGH PLANT USING ANIONIC ELPO AND THE SAMPLING DATA COLLECTED AT THE OSHAWA TRUCK PLANT USING ANIONIC ELPO ARE SIMILAR.

5. THIS INDICATES WE MIGHT EXPECT THE SAME KIND OF REDUCTION AT THE OSHAWA TRUCK PLANT WHEN IT CONVERTS TO A CATIONIC ELPO AS WAS EXPERIENCED AT THE SCARBOROUGH VAN PLANT.

THE CATIONIC ELPO PRIME PAINT DIP OPERATION IS THE MOST ADVANCED ELECTRODEPOSITION WATER BASE PRIME WITHIN, NOT ONLY GENERAL MOTORS CORPORATION, BUT THE PAINT INDUSTRY AS A WHOLE. WE ARE VERY PLEASED WITH THE CATIONIC ELPO IN THAT NO NEIGHBOURHOOD COMPLAINTS HAVE BEEN RECEIVED IN SCARBOROUGH SINCE THE PROCESS CHANGE IN AUGUST OF 1977.

AS NEW AND BETTER WAYS ARE DEVELOPED TO APPLY PAINT AND REDUCE EMISSIONS, WE IN GENERAL MOTORS WILL BE USING THEM WHEREVER POSSIBLE AND NECESSARY TO MAINTAIN OUR GOOD NEIGHBOUR POLICY AND AT THE SAME TIME ENSURE THE QUALITY OF OUR PRODUCT.

REFERENCES

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2. ONTARIO RESEARCH FOUNDATION REPORT 77-02
   EVALUATION OF ELPO OVEN EMISSIONS FOR AIR RESOURCES BRANCH, MINISTRY OF THE ENVIRONMENT AND GENERAL MOTORS OF CANADA LIMITED.

3. MINISTRY OF THE ENVIRONMENT RESULTS AND DATA FROM THE OSHAWA TRUCK PLANT ELPO OVEN EMISSIONS EVALUATION.

ACIDIC PRECIPITATION

by
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Air Resources Branch,
Ministry of the Environment.

The term acidic or "acid" precipitation has been heard with increasing frequency in recent years. This is no doubt in large part due to the increased effort expended in studying precipitation composition in the past 15 years in Europe and more recently in the United States and Canada. These studies have resulted in numerous allegations, much conjecture and, unfortunately, there still exists a paucity of reliable experimental data.

Then just what is acidic precipitation? Strictly speaking, any solution which has a pH less than 7.0 is acidic. If one uses this definition, then precipitation has probably been acidic for many hundreds, even thousands of years. Nature has arranged this via the presence of $C0_2$ in the atmosphere. Currently there is roughly 330 ppm (v) or 0.033% $C0_2$ in the atmosphere, measured at a background location, that is, removed from local sources in a well mixed air mass.

A certain amount of this atmospheric $C0_2$ will dissolve in precipitation droplets as they form in clouds. When $C0_2$ dissolves in H_20, some of it associates with H_20 molecules to form H_2C0_3, a weak acid, which dissociates to a small extent, thus acidifying the precipitation. The presence of roughly 300 ppm of $C0_2$ in the atmosphere results in a precipitation of pH of 5.6[(1)]. Background precipitation pH measurements are consistent with the value.

Then why is there the relatively recent concern about acidic precipitation in certain areas of the world such as Europe and northeastern North America? The reason is that the measured pH of precipitation in these areas is significantly less than 5.6 and this is what is generally referred to as acidic or "acid precipitation". Thus, acidic precipitation is any precipitation with a pH less than 5.6.

In northeastern North America the pH of precipitation is typically found to be between 3.0 and 5.0 with a mean value in the vicinity of 4.0. This is illustrated in Figures 1, 2, 3,[2] and 4[3]. A value of 4.0 corresponds to a 10^{-4} molar nitric or 5×10^{-5} molar sulfuric acid solutions (0.00063 and 0.00049% by weight respectively). Admittedly these are rather weakly acidic solutions but even these in sufficient quantity can have significant consequences, as will be described briefly below.

EFFECTS

For example, there is broad general agreement that the greatest potential impact of acidic precipitation is on aquatic ecosystems. The available evidence indicates relatively insignificant effects on vegetation or soils[4]. The effect on materials is not well understood and would be extremely difficult to quantify with an acceptable degree of reliability.

The aquatic ecosystems most susceptible to adverse effects by acidic precipitation are those located in lake waters of relatively low buffering capacity, because the pH of these waterbodies is more sensitive to the acidity of the precipitation they receive. There is now general agreement within the scientific community in Europe that hundreds of lakes in Scandinavia have been adversely affected by acidic precipitation.

There exists in Canada a large number of poorly buffered lakes which make them susceptible to a pH drop via acidic precipitation. The areas containing the most susceptible lakes are shown in Figure 5[5]. Recent work by Dillon and co-workers has discussed the location, effects and possible causes of some acidified lakes in various parts of Ontario[6,7], and a further discussion of this subject can be found there.

CAUSES

Before discussing the causes of acidic precipitation in Ontario, it would useful to discuss the various causal factors in a more general context. As has been already mentioned, atmospheric CO_2 reduces the pH of precipitation from 7.0 to around 5.6. One might well ask where the CO_2 in the atmosphere comes from. The current understanding of the global carbon cycle and measurements of atmospheric CO_2 at Mauna Loa since 1958 strongly imply that the vast bulk of the existing atmospheric CO_2 burden is natural in origin. Thus, nature herself has decided that precipitation should be acidic to some extent, having a pH of approximately 5.6 or containing 2.5×10^{-6} moles l^{-1} of H^+.

What, then, accounts for the frequently observed increased acidity of precipitation? The results of a number of studies, including those of Likens et al [8] and more recently Dillon and co-workers[6,7] and the MAP3S[10] have shown that the increased acidity is due virtually entirely to dissolved trace amounts of sulfates and nitrates, mainly in the form of sulfuric and nitric acids respectively. This can be seen from an examination of Table 1.

The vast bulk of these airborne sulfates and nitrates originates from the atmospheric oxidation of sulfur (SO_x) and nitrogen (NO_x) oxides respectively. The mechanisms of these processes will not be discussed here but suffice to say there exists some question as to which mechanisms dominate in the atmosphere.

Both SO_x and NO_x are produced in the combustion of fossil fuels and also from certain natural processes. Also a major source of man made SO_x is the non-ferrous smelters. The relative importance of natural and man made sources of atmospheric sulfur and nitrogen compounds is a matter of considerable uncertainty A recent estimate [11] places the ratio of man made to natural sources of sulfur in the atmosphere at 3:2 on a global scale. On a more

TABLE 1

WEIGHTED ANNUAL MEAN CONCENTRATIONS

HUBBARD BROOK EXPERIMENTAL FOREST

(from Reference 8)

SUBSTANCE	PRECIPITATION 1963-1974	
	mg/l	ueq/l *
H^+	0.073	72.4
NH_4^+	0.22	12.2
Ca^{2+}	0.16	7.98
Na^+	0.12	5.22
Mg^{2+}	0.04	3.29
K^+	0.07	1.79
Al^{3+}	---	---
SO_4^{2-}	2.9	60.3
NO_3^-	1.47	23.7
Cl^-	0.47	13.3
PO_4^{3-}	0.008	0.253
HCO_3^-	0.006	0.098
DISSOLVED SILICA	---	---
DISSOLVED ORGANIC CARBON	2.4	---
pH	4.14	
TOTAL:	8.64	(+) 102.9 (-) 97.7

* Sea Salt contributions not removed

reduced scale, such as northeastern North America, man made emissions likely assume a much greater significance. The atmospheric nitrogen cycle is even less well understood than the sulfur cycle, but as in the case of sulphur, man made emissions likely are important in certain regions of the globe.

The influence of a given source of SO_x or NO_x on the quality of precipitation falling on a given receptor region is a function of several factors including the following: the source strength, the height of the emissions, the air parcel trajectory, the distance between sources and receptor region, the chemical form of the emitted pollutants,the co-pollutants present (influences the form), and the storm type.

The influence of several of these factors is easy to visualize, while the influence of others is not so evident and I would like to briefly discuss two of them. Firstly, as an example of the importance of the chemical form of the emitted pollutant, in determining removal efficiency, consider the below cloud scavenging (washout) of SO_2 (gas) and $SO_4^=$ (particles or droplets) under the following conditions:

Polluted Parcel Depth	- 1500 m
Rainfall Rate	- 1 mm hr^{-1}
Raindrop Diameter	- 1 mm
Terminal Velocity of Raindrop	- 0.4 m s^{-1}
Contact or Traverse Time	- 1.04 hr

$(C/C_o)_{SO_2} \simeq 0.96$ whereas $(C/C_o)_{SO_4^=} \simeq 0.68$

where (C/C_o) is the ratio of the pollutant concentration in the polluted parcel after a rainfall of approximately one hour to that before the storm.

Thus, as shown in the above example, the washout of the $SO_4^=$ is much more efficient than that for SO_2.

Another factor that can be very important is that of the influence of storm type. Generally speaking, pollutant removal efficiency is greater for in cloud scavenging (rainout) than for washout. This is particularly true if there is a significant concentration of an oxidizing agent such as H_2O_2 or O_3 present in the cloud, as this would enhance the irreversible sorption of SO_2, NO_2 by the raindrop. Convective storms are known to produce both H_2O_2 and O_3,

It is not surprising, therefore, that, given the number of factors that can influence precipitation, a large variability in precipitation acidity at a given location has been observed from one storm to another[10,12].

Now having looked at some of the factors that can influence precipitation quality in a general way, I would like to discuss some of the causal factors affecting precipitation acidity in Ontario.

Figures 6,7,8,9, show the locations and source strengths of several of the more important man made sources of SO_x and NO_x to the atmosphere. As can be readily seen from these figures there are a large number of sources of SO_x and NO_x in the eastern U.S. and Canada. Also the number of sources and the quantity emitted by the American sources greatly exceeds that emitted in Ontario.

Figures 10, 11, 12, 13 illustrate an example of a storm path and show storm trajectories for summer and winter seasons. It is important to note that the trajectory of the air parcel, through which the precipitation is falling, is <u>not</u> the same as the storm trajectory. As a general rule, as illustrated by the previous figures, precipitation falling in Ontario is associated with maritime tropical air

originating over the Gulf of Mexico. Thus, any source of SO_x or NO_x between the Gulf and Ontario, in addition to these in Ontario can potentially contribute to precipitation acidity.

CURRENT PROGRAMMES

A number of studies on the formation, transport and monitoring of acidic precipitation are underway in Canada and the U.S. In Ontario, a number of groups have active programmes in precipitation monitoring. These efforts are illustrated in Figures 14, 15 showing the various monitoring sites in the Province. Figure 17 gives a more detailed view of the ARB/SES network. Table 2 lists the various parameters assayed in the SES network run by the ARB. Figures 17 and 18, indicate the deposition of $SO_4^=$ and NO_3^- due to precipitation for the months of June, July and August 1977. An examination of these figures as well as Figures 1,2 and 3 will show that they exhibit a similar pattern, that is, the deposition of $SO_4^=$, NO_3^- and the acidity of precipitation all decrease with increasing distance from the U.S. border.

Although these data are highly suggestive, they are not quantitative. However, given the abundance and strength of SO_x and NO_x sources in the U.S., the rate of atmospheric oxidation of SO_2 and NO to H_2SO_4 and HNO_3, the motion of weather systems and air parcel trajectories and the precipitation monitoring data available, it is most likely that a very significant portion of the acidic precipitation falling in Ontario is indeed imported. The relative contributions, on a Province wide basis, of distant and local sources cannot be quantitatively stated at this time, but work is underway in both the Sudbury Environmental Study and the Nanticoke Environmental Management Programme to determine, for these areas, the respective contributions.

TABLE 2

PARAMETERS FOR ANALYSIS

SES PRECIPITATION NETWORK

AIR RESOURCES BRANCH

1. pH
2. TOTAL ACIDITY
3. $SO_4^{=}$
4. NO_3
5. NH_4^{+}
6. Br^{-}
7. Cl^{-}
8. Ca
9. Mg
10. Na
11. K
12. Si
13. Fe
14. Co
15. Ni
16. Pb
17. Zn
18. Al
19. Cr
20. V

Work is also underway by Environment Canada to characterize the phenomenon on a national scale in addition to a number of multi-purpose projects underway in the U.S. (e.g., MAP3S, STATE, USDA).

As the understanding of the phenomenon improves with the increasing reservoir of reliable information over the coming years, regulatory agencies will be in a much better position to implement effective, rational control strategies.

ACKNOWLEDGEMENT

The authors gratefully acknowledge several helpful discussions with J. Kurtz of the Air Quality and Meteorology Section of the Air Resources Branch.

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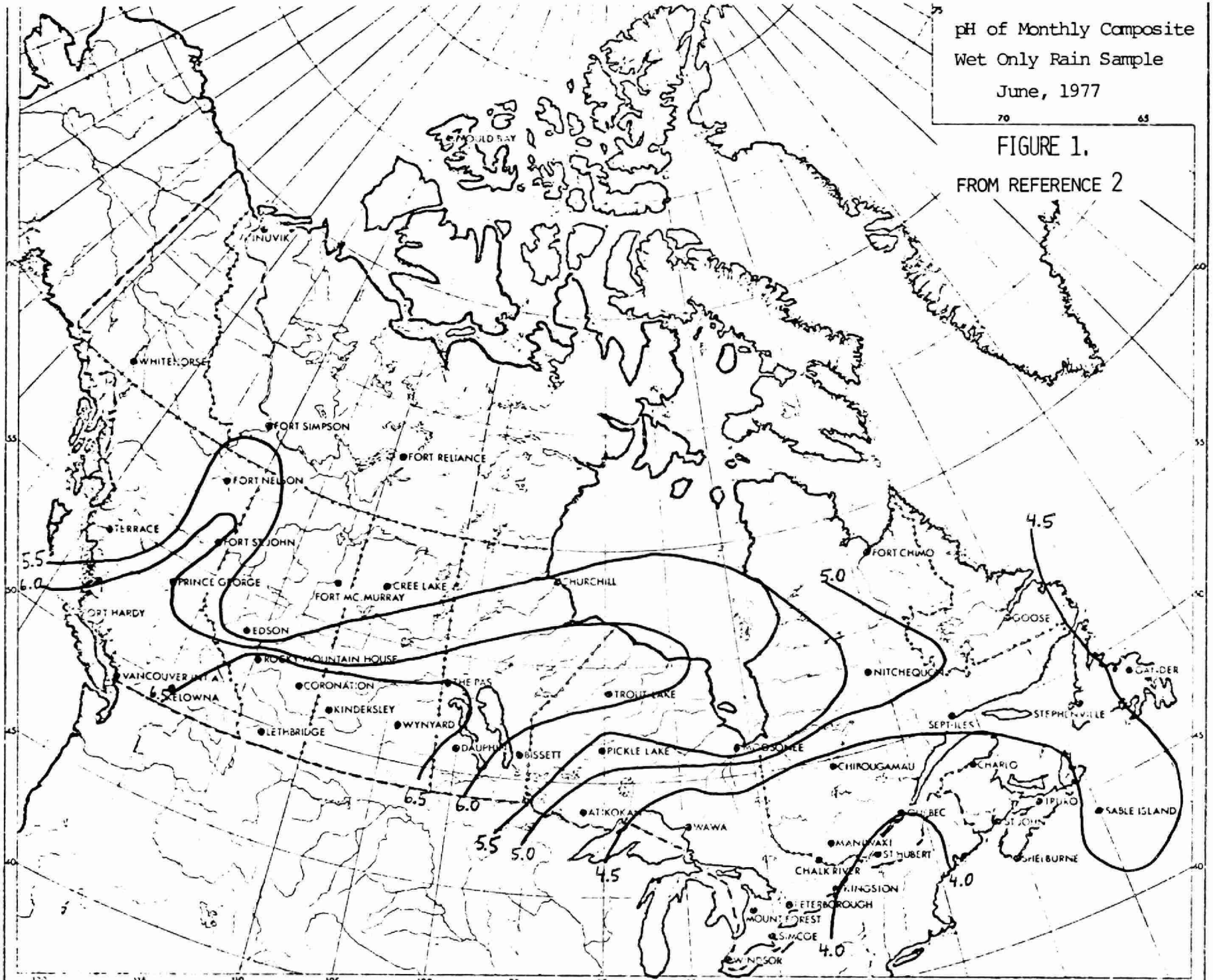
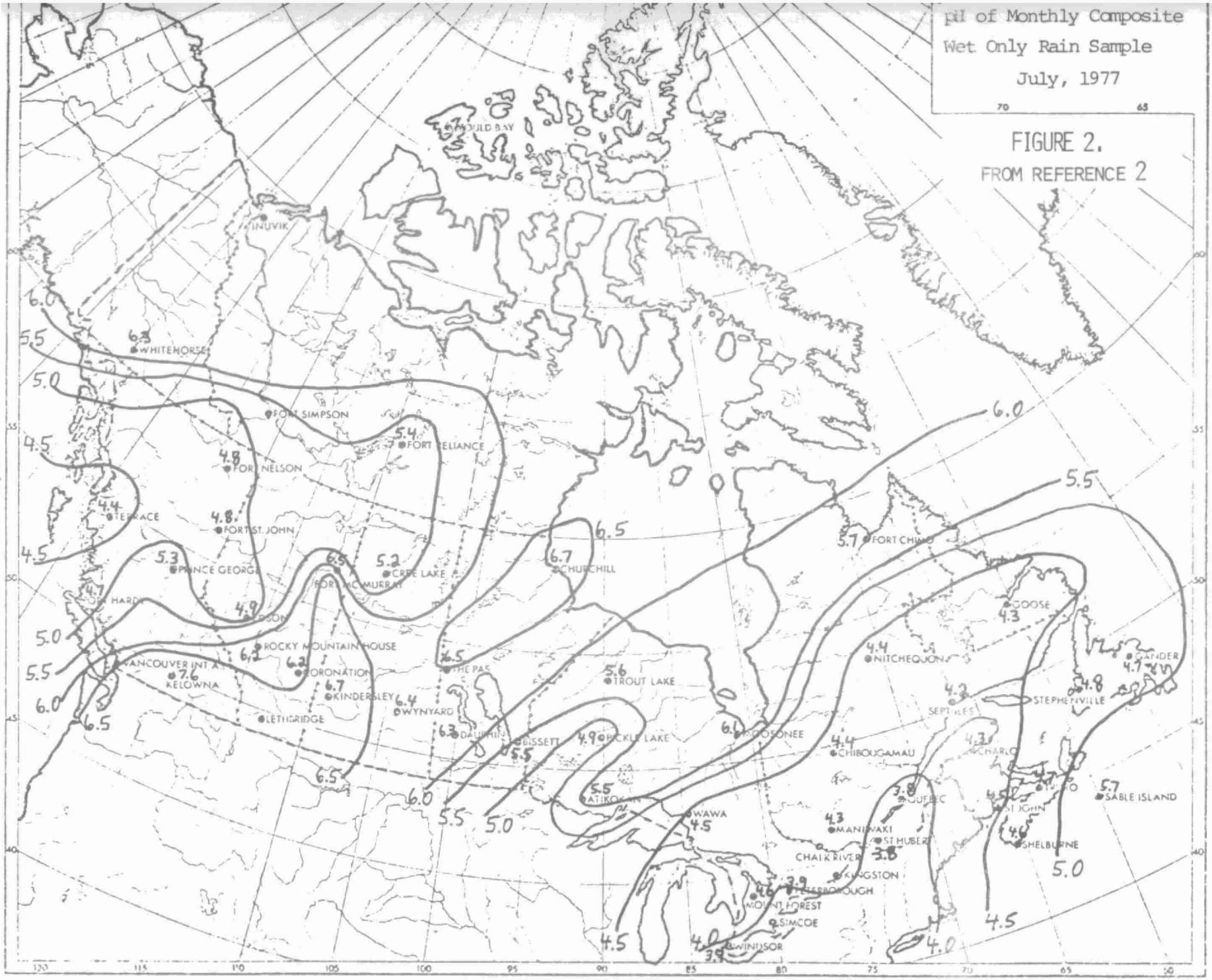
11. L. Granat, R.O. Hallberg and H. Rodhe; SCOPE Report 7 Ecol. Bull, (Stockholm) 22: 39-134 (1976).

12. J. Hales; Private Communication.


pH of Monthly Composite
Wet Only Rain Sample
June, 1977
FIGURE 1.
FROM REFERENCE 2
INUVIK
WHITEHORSE
FORT SIMPSON
FORT RELIANCE
FORT NELSON
TERRACE
FORT ST JOHN
PRINCE GEORGE
CREE LAKE
FORT MC MURRAY
CHURCHILL
FORT CHIMO
GOOSE
EDSON
ROCKY MOUNTAIN HOUSE
VANCOUVER INT'A
KELOWNA
CORONATION
THE PAS
TROUT LAKE
NITCHEQUON
KINDERSLEY
WYNYARD
LETHBRIDGE
DAUPHIN
BISSETT
PICKLE LAKE
SEPT-ILES
STEPHENVILLE
CHIBOUGAMAU
CHARLO
SABLE ISLAND
ATIKOKAN
SAWA
MANIWAKI
ST HUBERT
CHALK RIVER
KINGSTON
PETERBOROUGH
MOUNT FOREST
S.SIMCOE
WINDSOR
SHELBURNE
4.5
5.0
5.5
6.0
6.5
4.0


pH of Monthly Composite
Wet Only Rain Sample
July, 1977
FIGURE 2.
FROM REFERENCE 2
INUVIK
WHITEHORSE
FORT SIMPSON
FORT NELSON
FORT LIARD
TERRACE
FORT ST. JOHN
PRINCE GEORGE
CREE LAKE
FORT MCMURRAY
CHURCHILL
FORT CHIMO
ROCKY MOUNTAIN HOUSE
VANCOUVER INT. A.
KELOWNA
CORONATION
KINDERSLEY
LETHBRIDGE
WYNYARD
THE PAS
TROUT LAKE
NITCHEQUON
GOOSE
STEPHENVILLE
SEPT ILES
PICKLE LAKE
MOOSONEE
CHIBOUGAMAU
QUEBEC
ST JOHN
SABLE ISLAND
SHELBURNE
WAWA
MANITOWAKI
ST HUBERT
CHALK RIVER
KINGSTON
PETERBOROUGH
MOUNT FOREST
SIMCOE
WINDSOR
ATIKOKAN
BISSETT
DAUPHIN
6.0
5.5
5.0
4.5
6.5

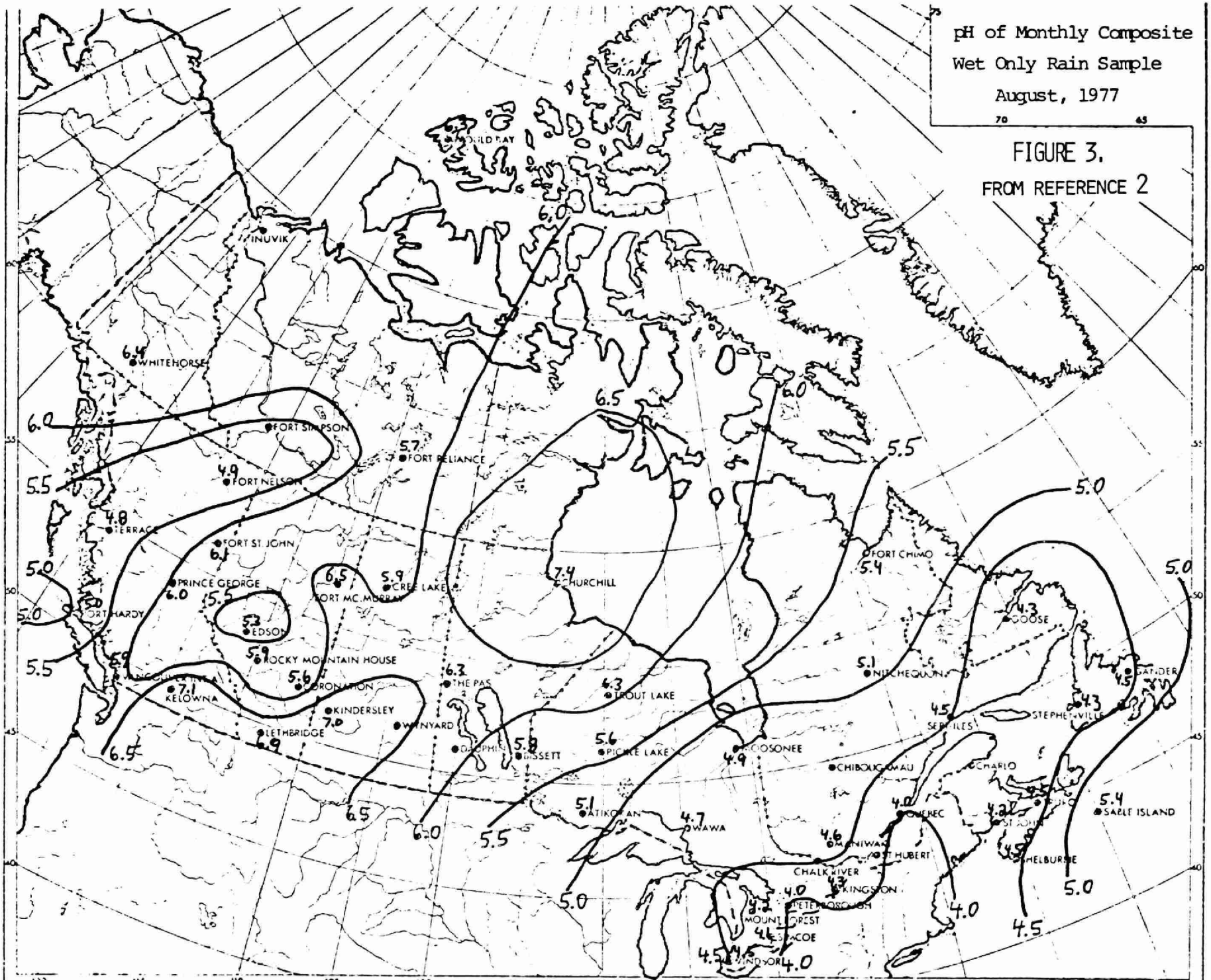
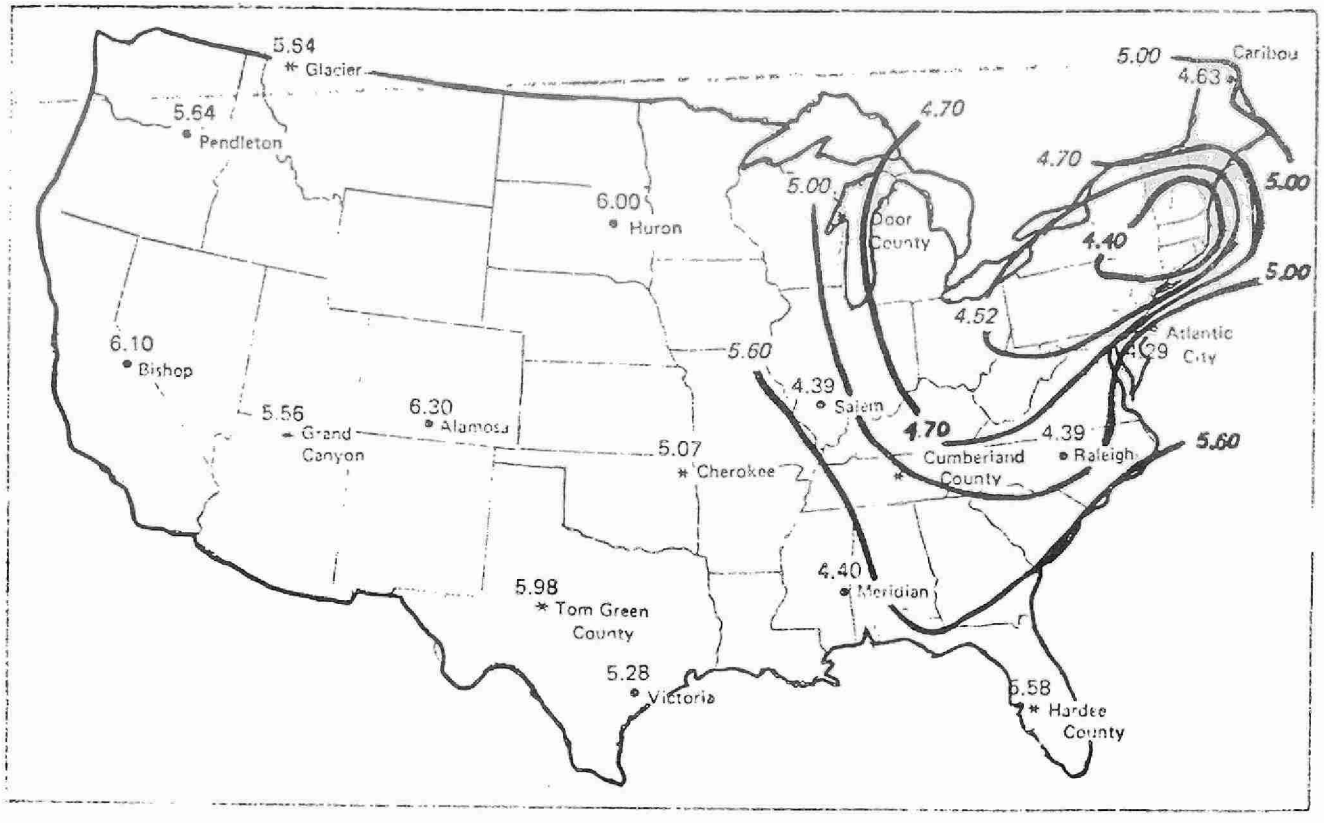

pH of Monthly Composite
Wet Only Rain Sample
August, 1977
70
45
FIGURE 3.
FROM REFERENCE 2
INUVIK
WHITEHORSE
FORT SIMPSON
FORT RELIANCE
FORT NELSON
TERRACE
FORT ST. JOHN
PRINCE GEORGE
FORT MC MURRAY
CREE LAKE
EDSON
ROCKY MOUNTAIN HOUSE
CORONATION
KELOWNA
KINDERSLEY
LETHBRIDGE
WYNYARD
THE PAS
DISSETT
TROUT LAKE
PICKLE LAKE
CHURCHILL
FORT CHIMO
GOOSE
NITCHEQUON
SEPT-ILES
STEPHENVILLE
GANDER
SABLE ISLAND
TIMMINS
SUDBURY
CHALK RIVER
KINGSTON
MOUNT FOREST
BARRIE
WINDSOR
6.0
6.5
5.5
5.0
4.5
4.0

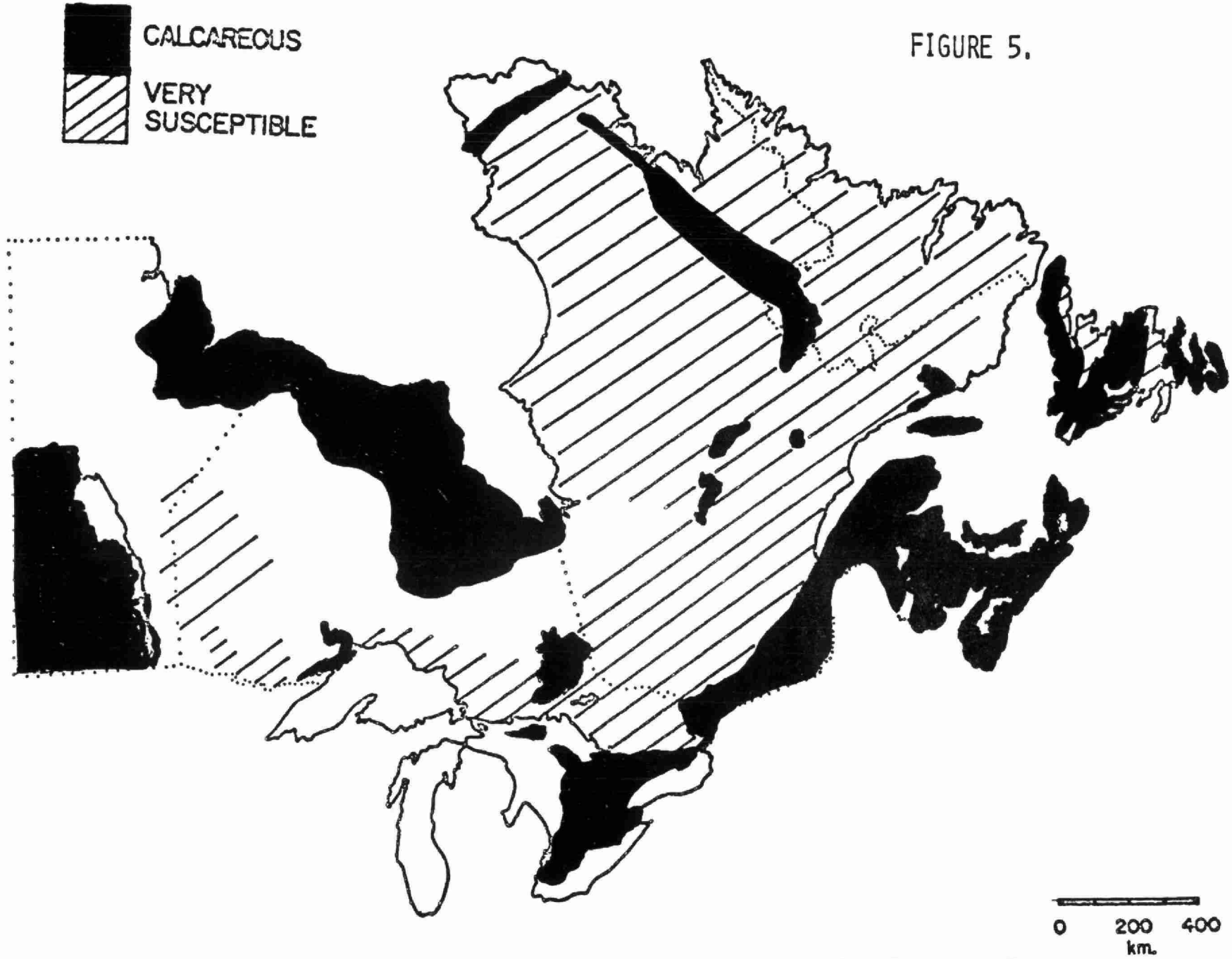
FIGURE 4.



CALCULATED pH OF PRECIPITATION OVER THE EASTERN U.S. DURING 1965-66

FROM REFERENCE 3

FIGURE 5.



DISTRIBUTION OF FRESHWATER BUFFERING CAPACITY IN EASTERN CANADA - FROM REFERENCE 5.

FIGURE 6. (FROM REFERENCE 9)

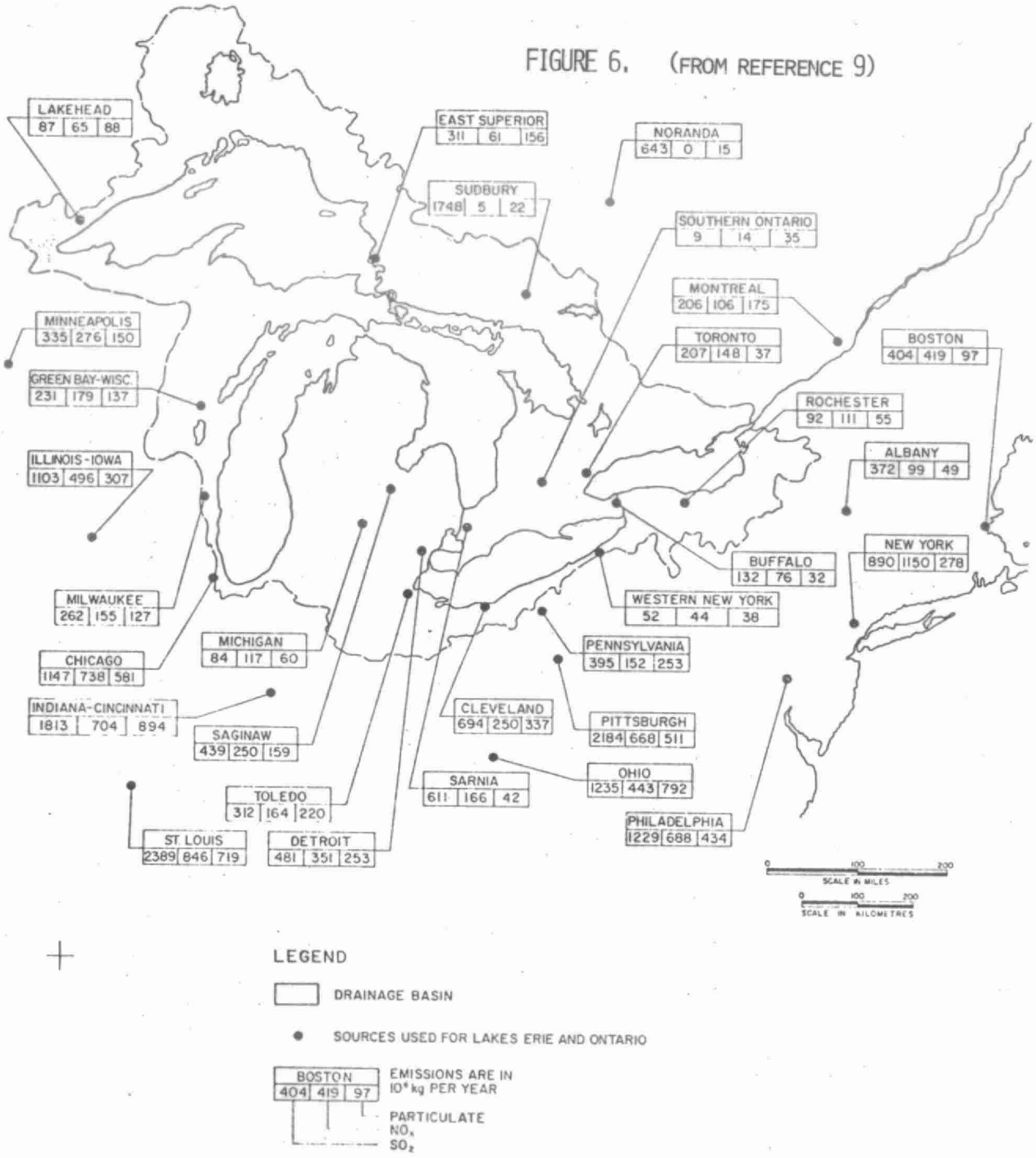


FIGURE 7.

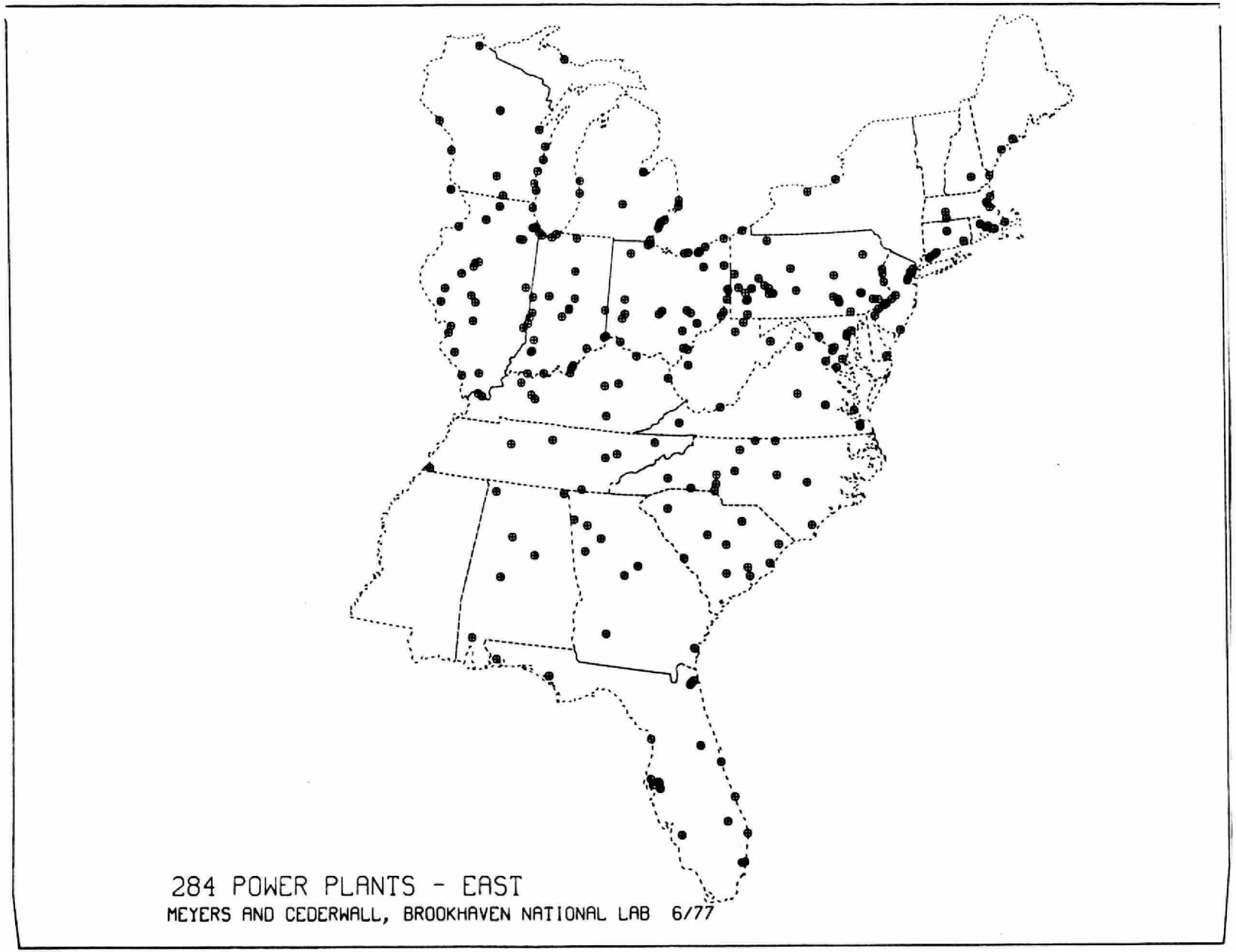

284 POWER PLANTS - EAST
MEYERS AND CEDERWALL, BROOKHAVEN NATIONAL LAB 6/77

FIGURE 8. DATA FROM AIR QUALITY & METEOROLOGY SECTION OF THE AIR RESOURCES BRANCH

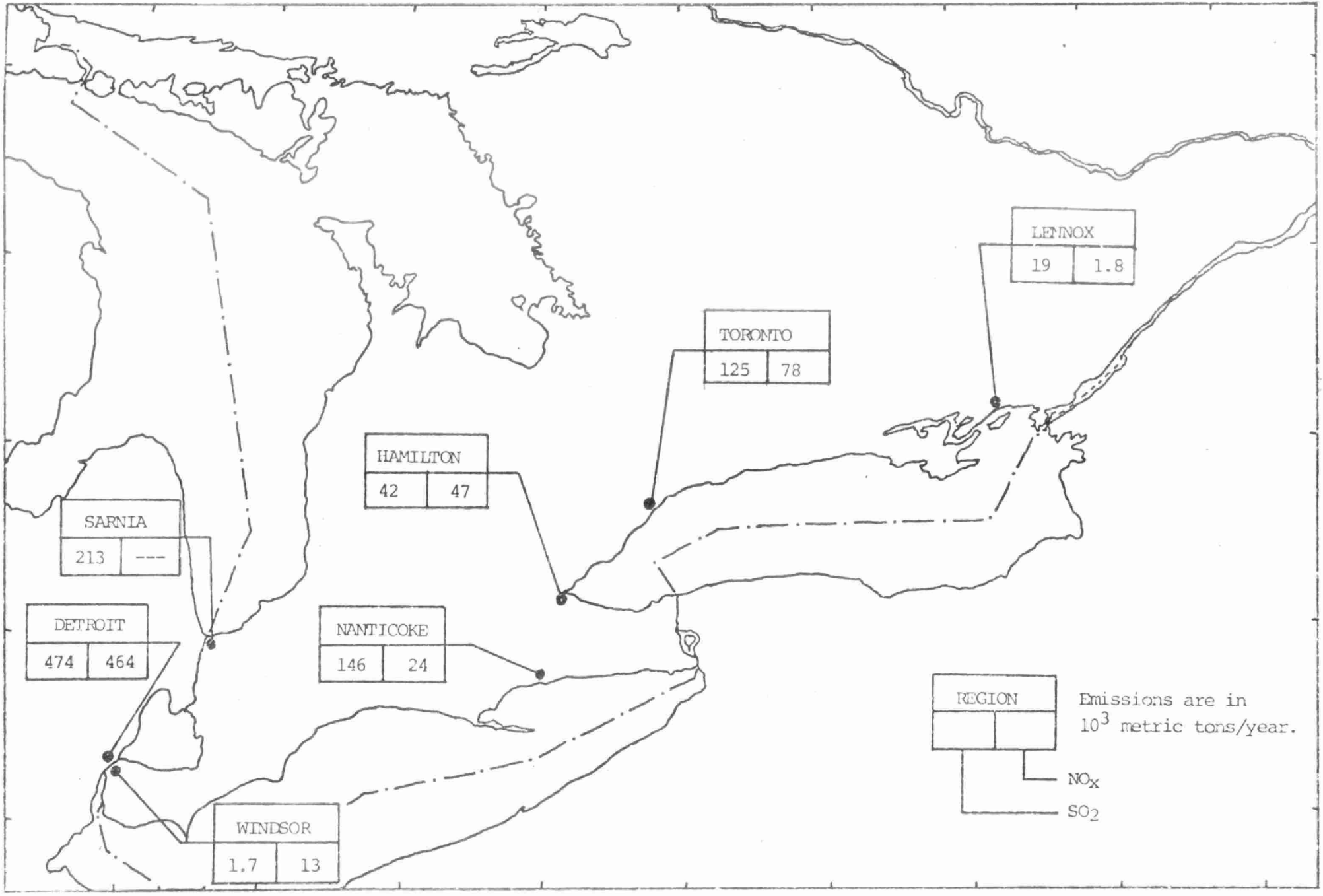


FIGURE 9 DATA FROM AIR QUALITY & METEOROLOGY SECTION OF THE AIR RESOURCES BRANCH

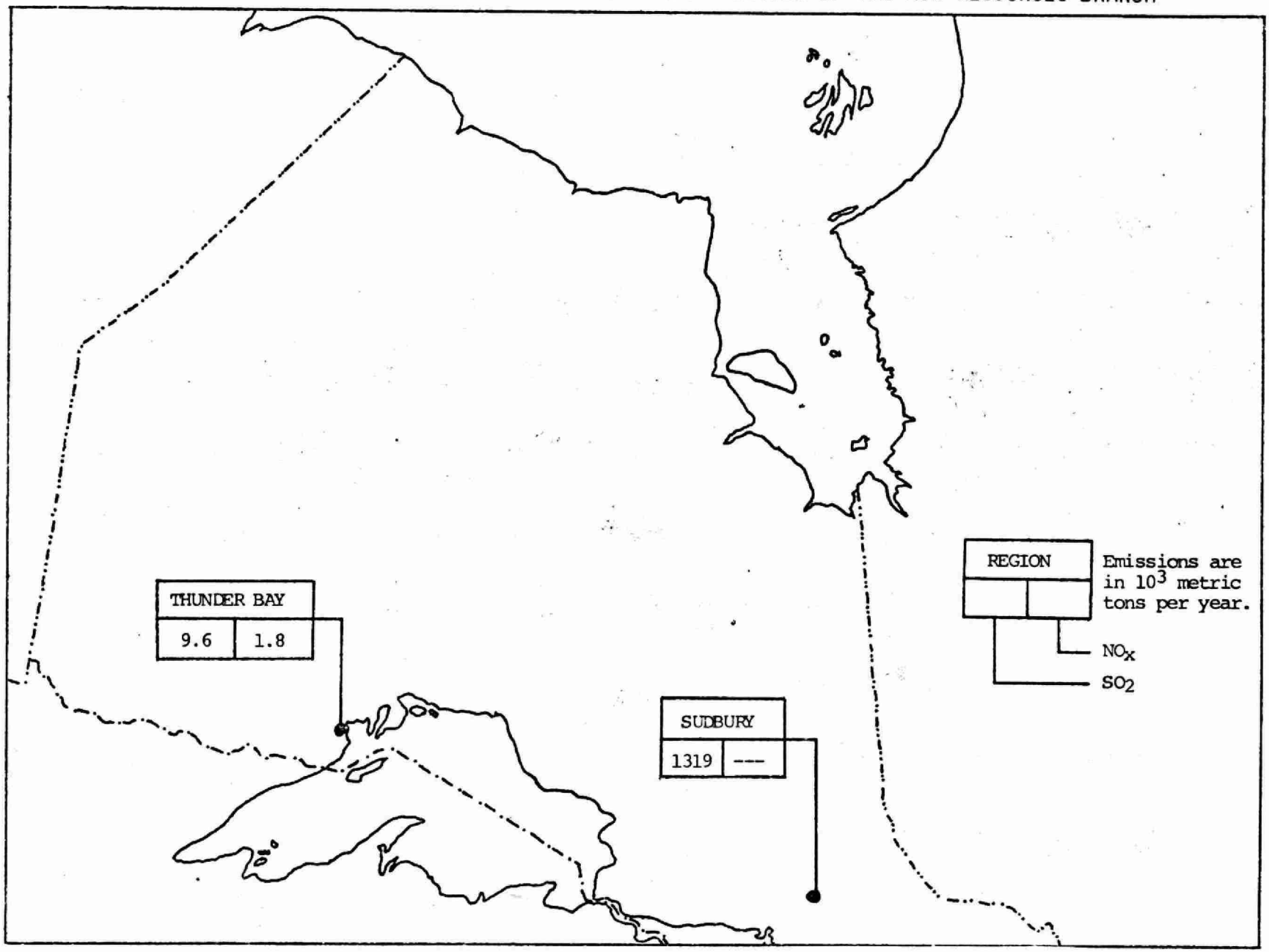
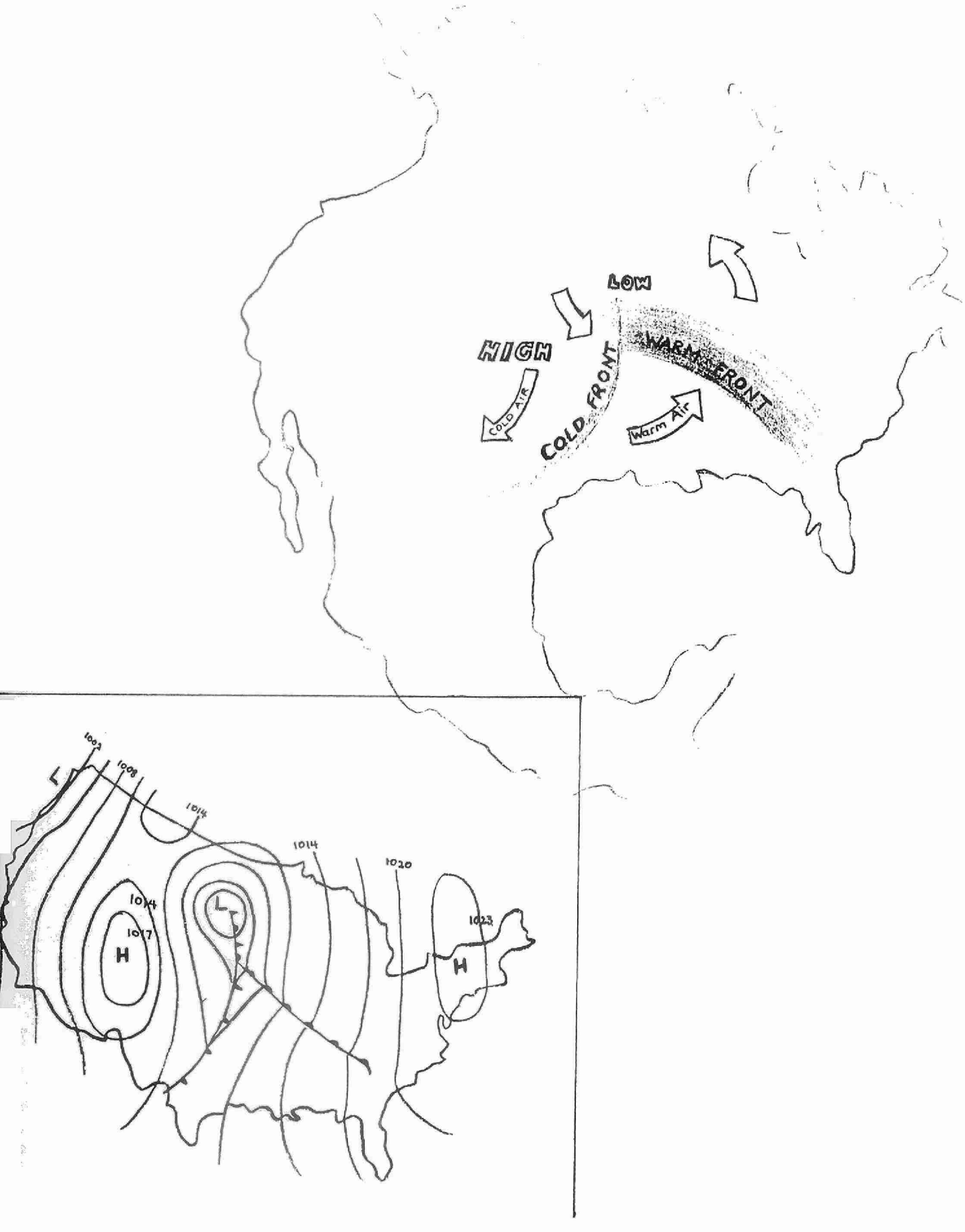


FIGURE 10


LOW
HIGH
COLD AIR
COLD FRONT
WARM FRONT
Warm Air
1002
1008
1014
1014
1020
1014
1017
H
1023
H

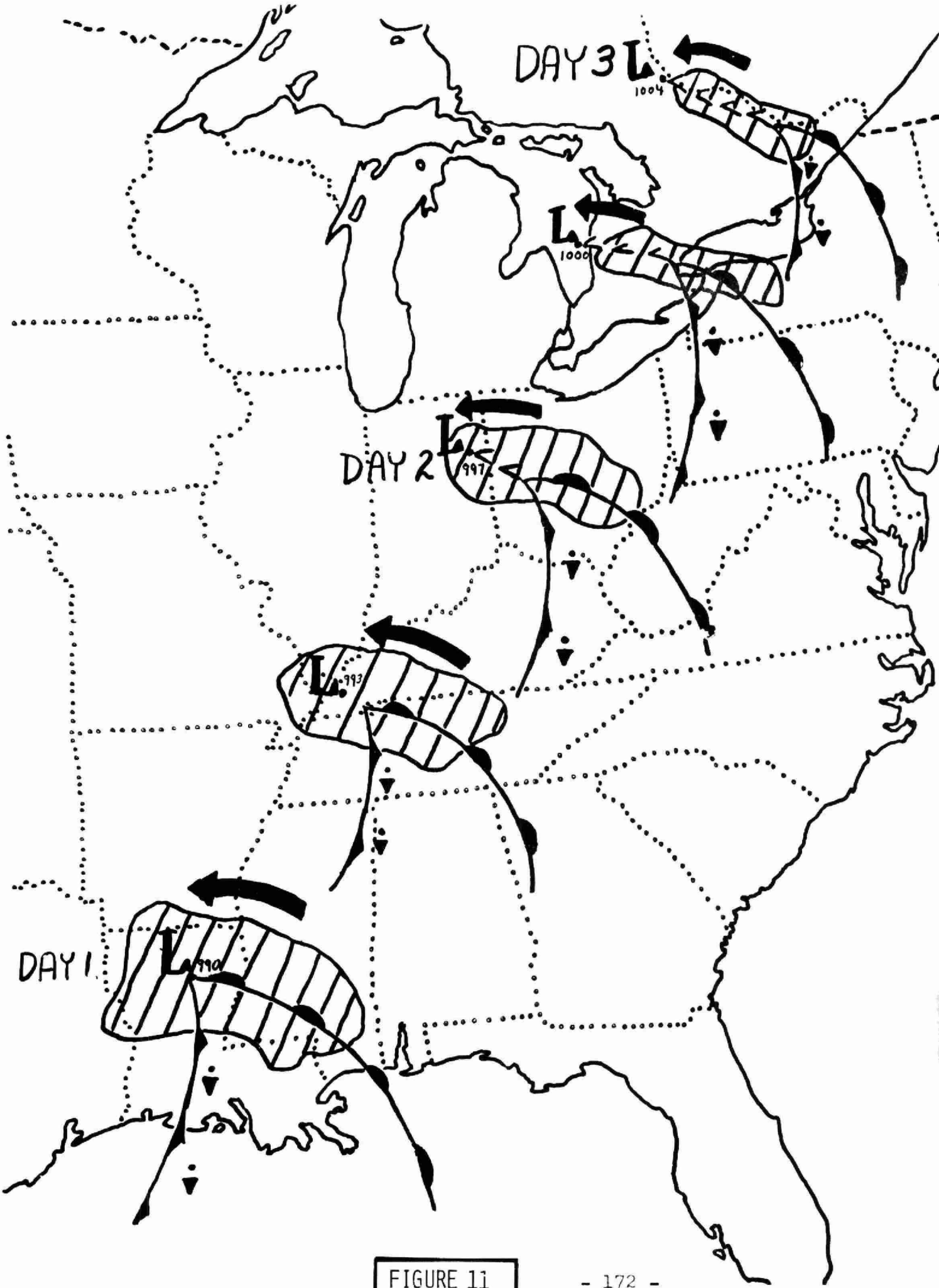


FIGURE 11

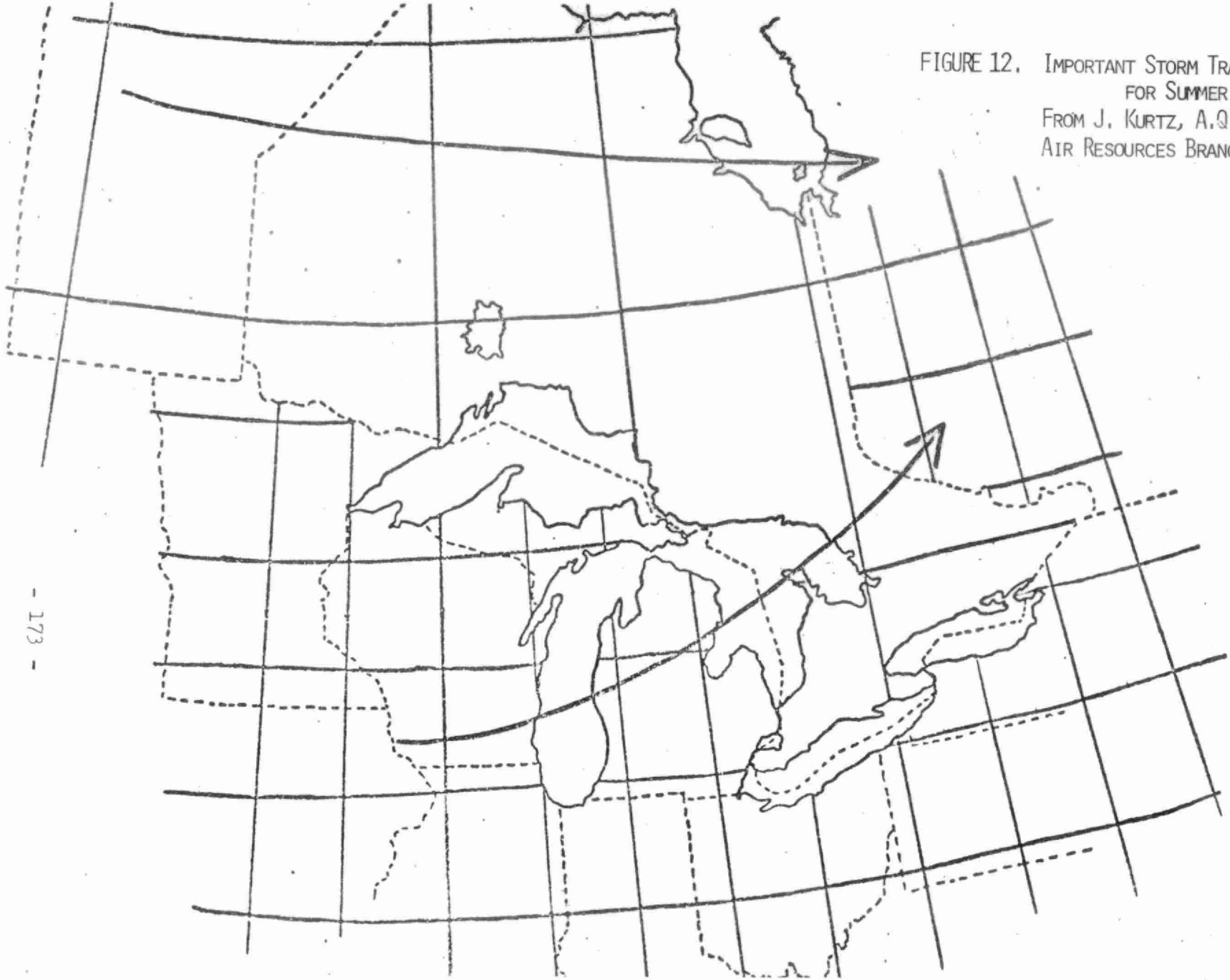


FIGURE 12. IMPORTANT STORM TRAJECTORIES FOR SUMMER
FROM J. KURTZ, A.Q.M. SECTION, AIR RESOURCES BRANCH.

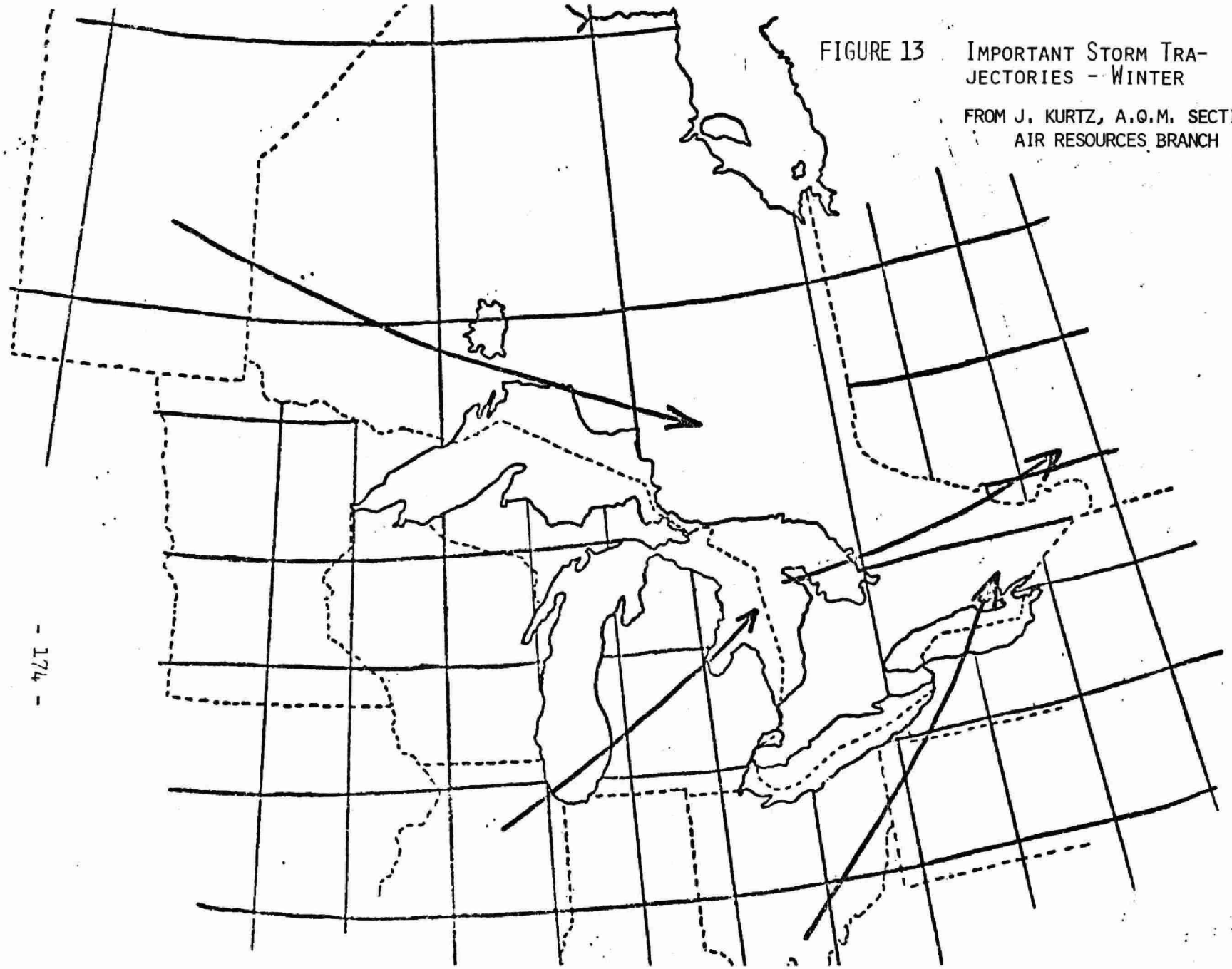
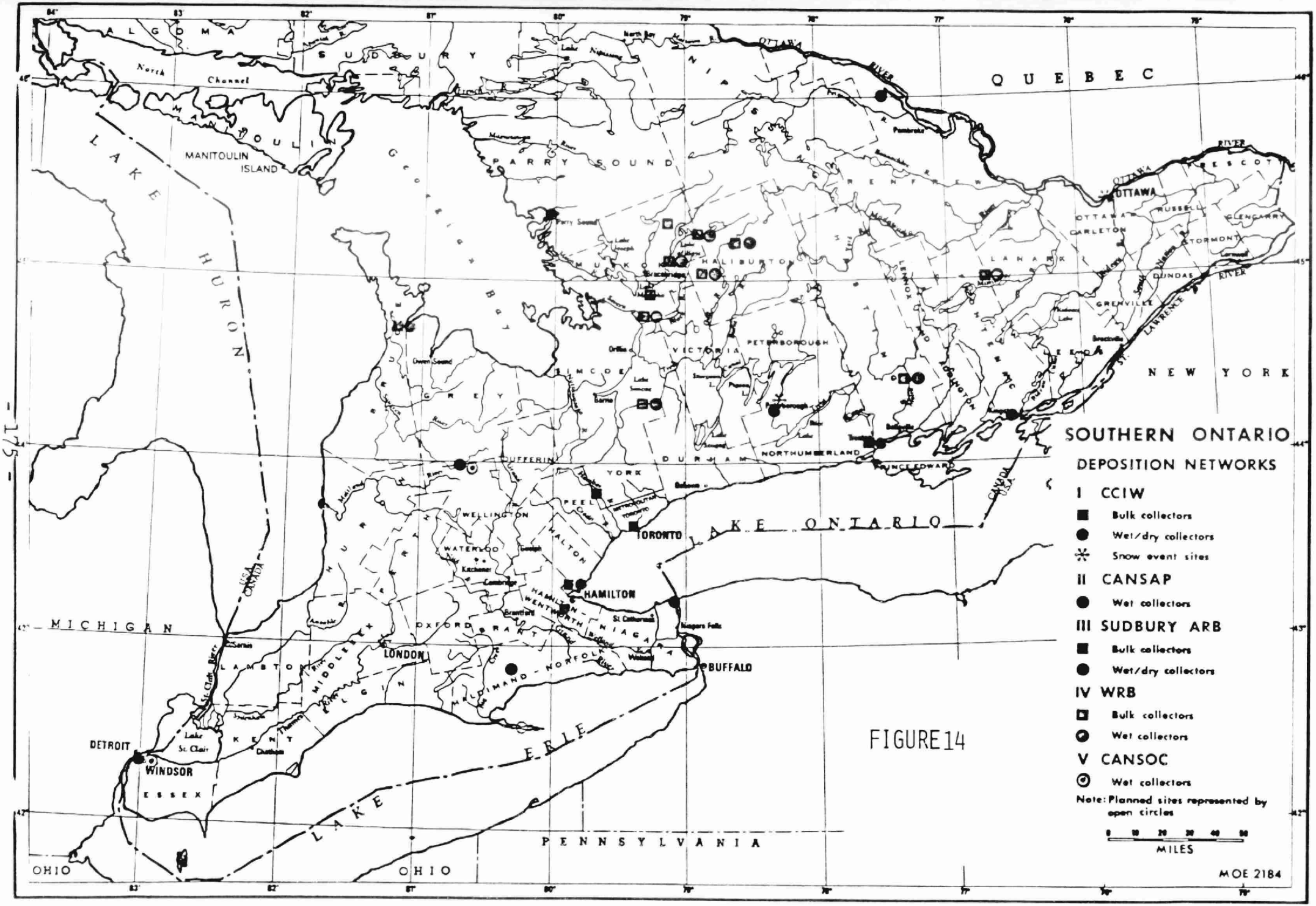


FIGURE 13 IMPORTANT STORM TRAJECTORIES - WINTER

FROM J. KURTZ, A.Q.M. SECTION, AIR RESOURCES BRANCH


SOUTHERN ONTARIO
DEPOSITION NETWORKS
I CCIW
Bulk collectors
Wet/dry collectors
Snow event sites
II CANSAP
Wet collectors
III SUDBURY ARB
Bulk collectors
Wet/dry collectors
IV WRB
Bulk collectors
Wet collectors
V CANSOC
Wet collectors
Note: Planned sites represented by open circles
MILES
MOE 2184
FIGURE 14
LAKE HURON
LAKE ONTARIO
LAKE ERIE
QUEBEC
NEW YORK
MICHIGAN
OHIO
PENNSYLVANIA
TORONTO
HAMILTON
LONDON
BUFFALO
DETROIT
WINDSOR
OTTAWA
MANITOULIN ISLAND
SUDBURY
PARRY SOUND
HALIBURTON
VICTORIA
PETERBOROUGH
NORTHUMBERLAND
DURHAM
YORK
PEEL
HALTON
WELLINGTON
WATERLOO
GREY
SIMCOE
DUFFERIN
OXFORD
BRANT
NIAGARA
MIDDLESEX
ELGIN
KENT
ESSEX
LAMBTON
HURON
RENFREW
LANARK
GRENVILLE
DUNDAS
STORMONT
RUSSELL
GLENGARRY
CARLETON
PRESCOTT
RIVER
ST. LAWRENCE
CANADA
U.S.A.

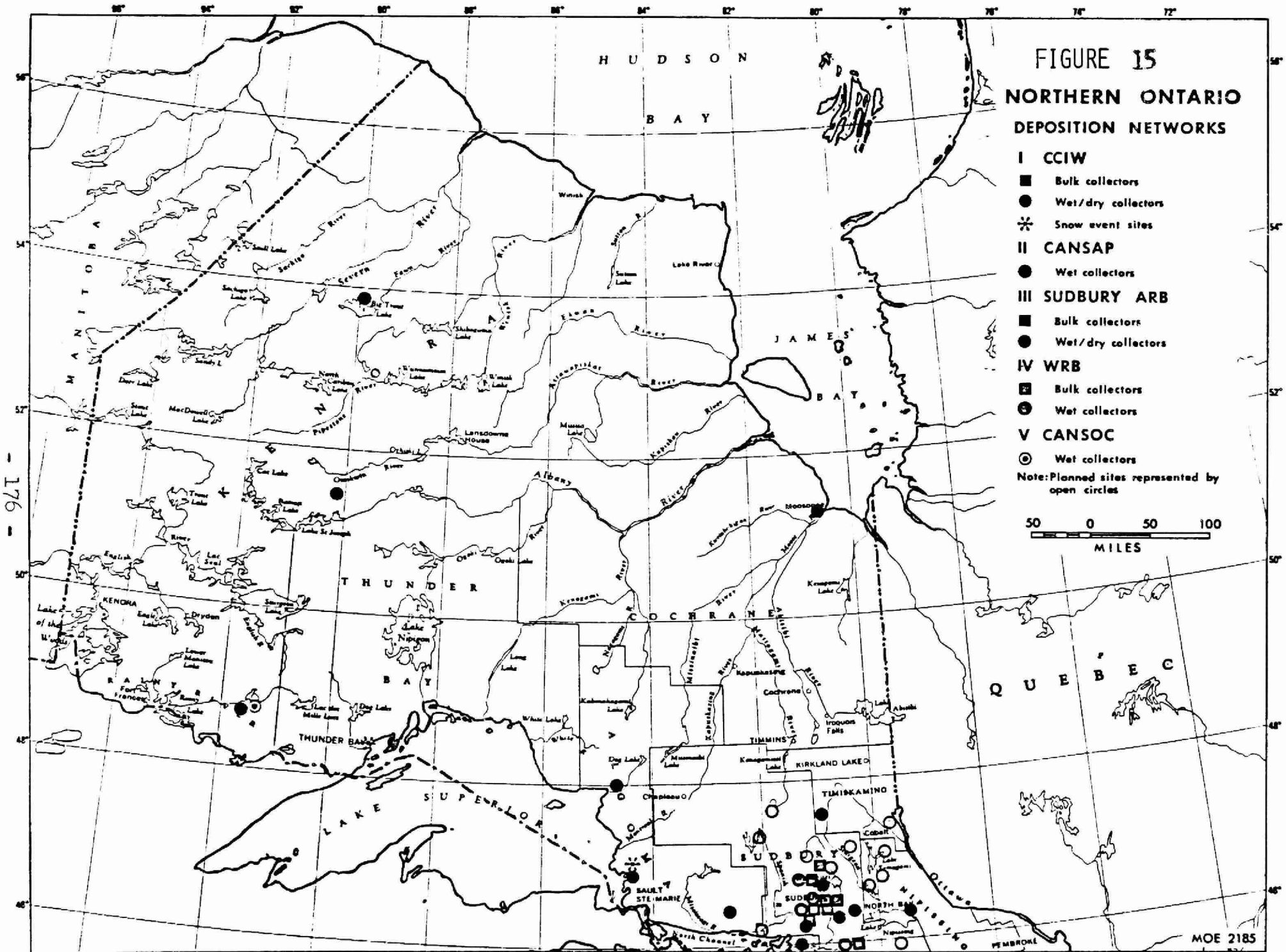
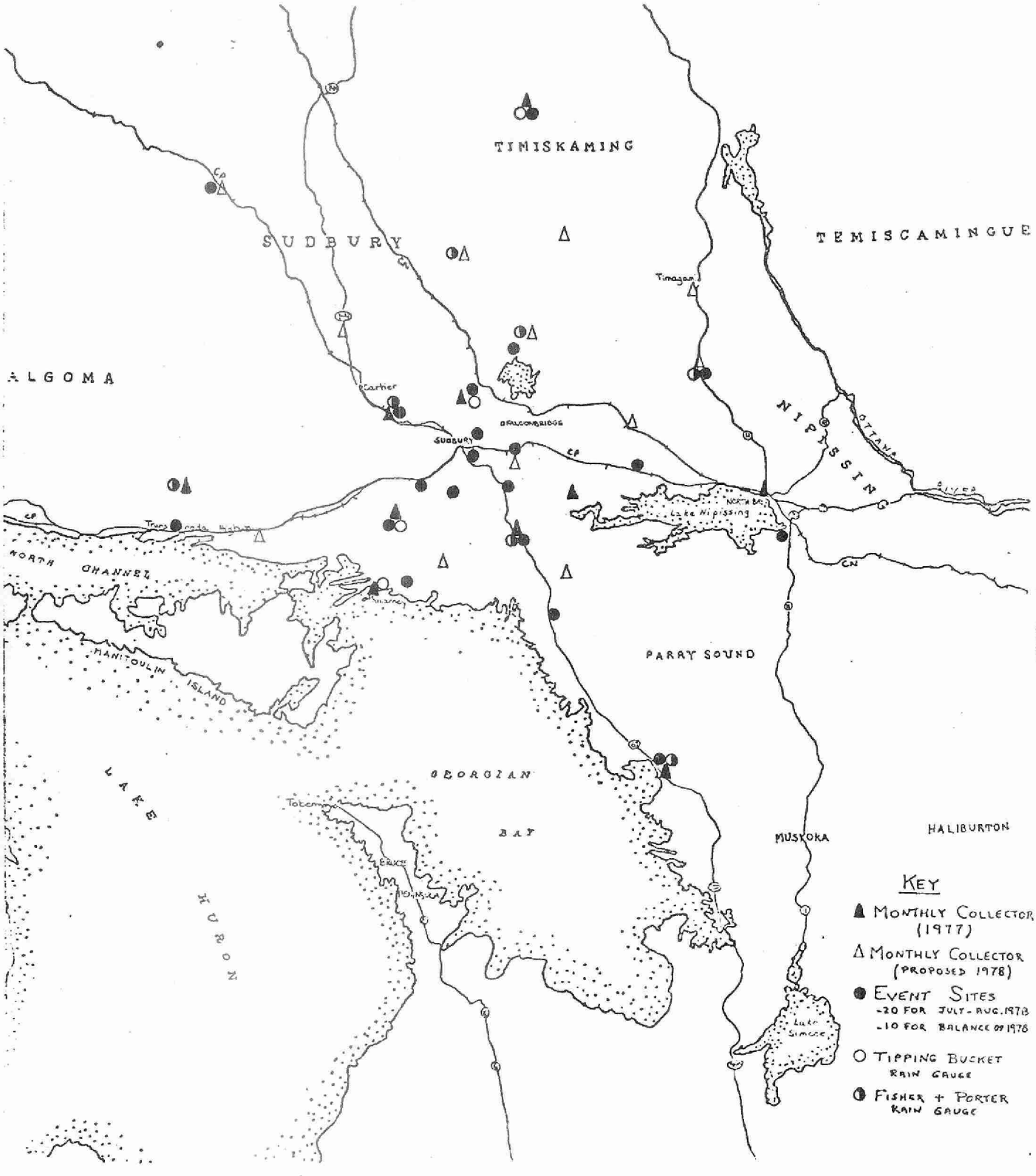
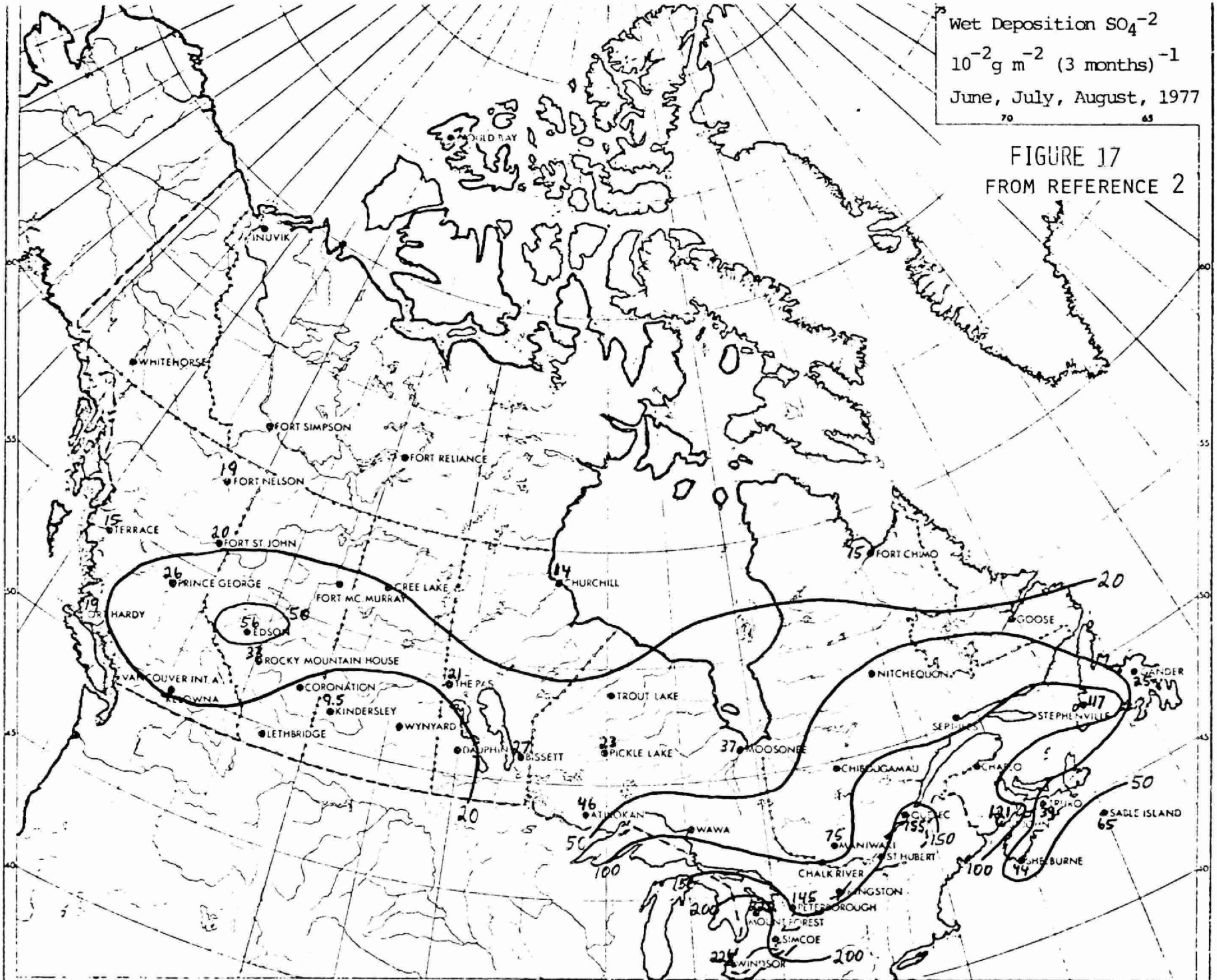
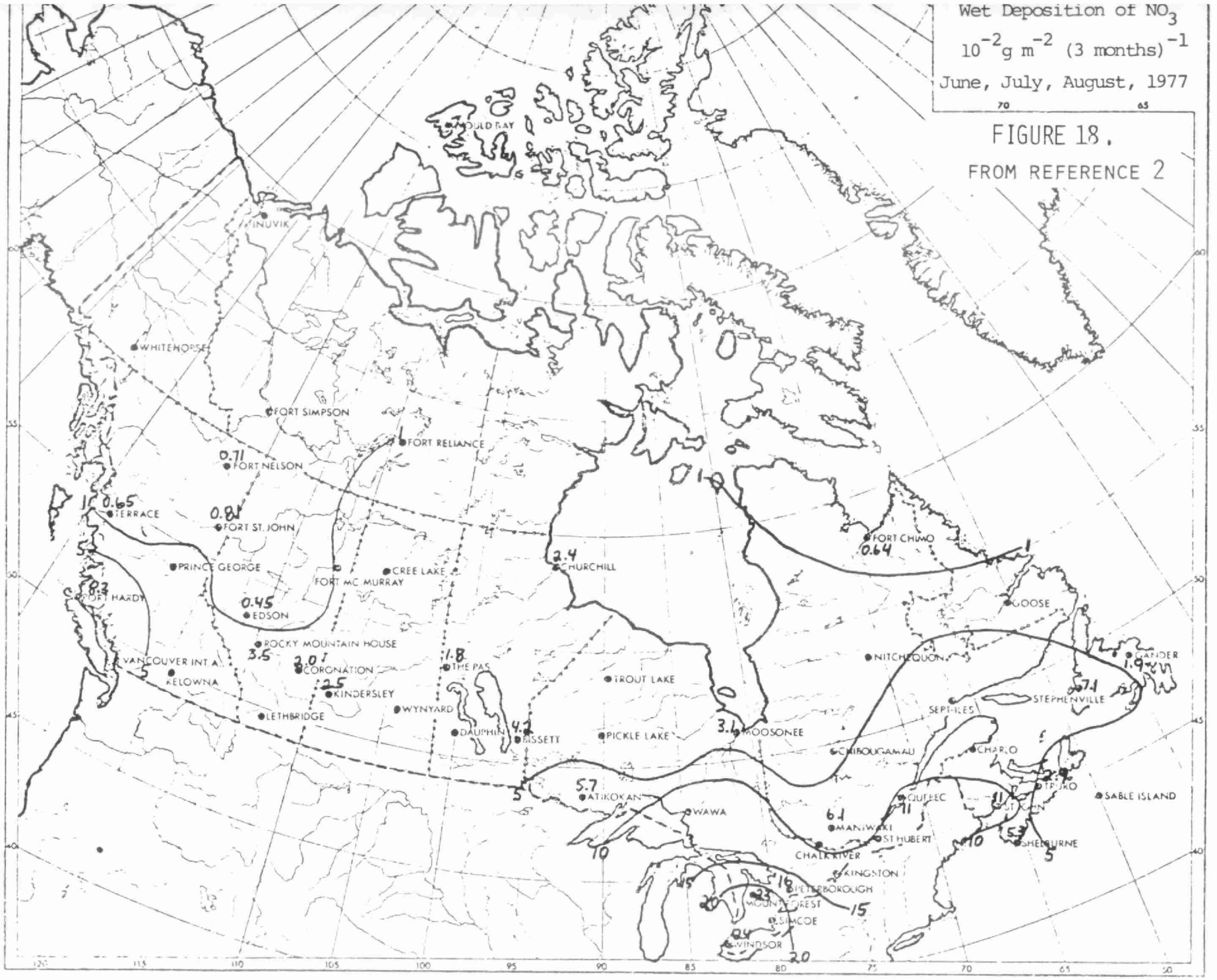


FIGURE 15
NORTHERN ONTARIO
DEPOSITION NETWORKS
I CCIW
Bulk collectors
Wet/dry collectors
Snow event sites
II CANSAP
Wet collectors
III SUDBURY ARB
Bulk collectors
Wet/dry collectors
IV WRB
Bulk collectors
Wet collectors
V CANSOC
Wet collectors
Note: Planned sites represented by open circles
50 0 50 100
MILES
HUDSON BAY
JAMES BAY
QUEBEC
MANITOBA
ONTARIO
THUNDER BAY
LAKE SUPERIOR
TIMMINS
KIRKLAND LAKE
TIMISKAMING
SAULT STE. MARIE
SUDBURY
NORTH BAY
PEMBROKE
COCHRANE
KENORA
MOE 2185

FIGURE 16


TIMISKAMING
SUDBURY
TEMISCAMINGUE
ALGOMA
NIPISSING
PARRY SOUND
MUSKOKA
HALIBURTON
GEORGIAN BAY
LAKE HURON
NORTH CHANNEL
MANITOULIN ISLAND
Timagami
Earlton
FALCONBRIDGE
SUDBURY
Lake Nipissing
Lake Simcoe
KEY
MONTHLY COLLECTOR (1977)
MONTHLY COLLECTOR (PROPOSED 1978)
EVENT SITES
-20 FOR JULY - AUG. 1978
-10 FOR BALANCE OF 1978
TIPPING BUCKET RAIN GAUGE
FISHER + PORTER RAIN GAUGE


Wet Deposition SO_4^{-2}
10^{-2} g m^{-2} (3 months)$^{-1}$
June, July, August, 1977
FIGURE 17
FROM REFERENCE 2
INUVIK
WHITEHORSE
FORT SIMPSON
FORT RELIANCE
FORT NELSON
TERRACE
FORT ST JOHN
PRINCE GEORGE
FORT MC MURRAY
CREE LAKE
HURCHILL
FORT CHIMO
HARDY
EDSON
ROCKY MOUNTAIN HOUSE
GOOSE
VANCOUVER INT A
KELOWNA
CORONATION
KINDERSLEY
THE PAS
TROUT LAKE
NITCHEQUON
LETHBRIDGE
WYNYARD
DAUPHIN
BISSETT
PICKLE LAKE
MOOSONEE
STEPHENVILLE
CHIBOUGAMAU
CHAPEAU
ATIKOKAN
WAWA
MANIWAKI
ST HUBERT
CHALK RIVER
SABLE ISLAND
SHEARWATER
KINGSTON
PETERBOROUGH
MOUNT FOREST
SIMCOE
WINDSOR


Wet Deposition of NO_3^-
10^{-2} g m^{-2} (3 months)$^{-1}$
June, July, August, 1977
FIGURE 18.
FROM REFERENCE 2
PROUD BAY
INUVIK
WHITEHORSE
FORT SIMPSON
FORT RELIANCE
FORT NELSON
TERRACE
FORT ST. JOHN
PRINCE GEORGE
FORT MC MURRAY
CREE LAKE
CHURCHILL
FORT CHIMO
GOOSE
PORT HARDY
EDSON
ROCKY MOUNTAIN HOUSE
VANCOUVER INT A
KELOWNA
CORONATION
KINDERSLEY
THE PAS
TROUT LAKE
NITCHEQUON
GANDER
STEPHENVILLE
SEPT-ILES
WYNYARD
LETHBRIDGE
DAUPHIN
ISSETT
PICKLE LAKE
MOOSONEE
CHIBOUGAMAU
CHARLO
ATIKOKAN
WAWA
QUEBEC
TRURO
SABLE ISLAND
MANIWAKI
ST HUBERT
CHALK RIVER
SHELBURNE
KINGSTON
PETERBOROUGH
MOUNT FOREST
SIMCOE
WINDSOR
0.71
0.65
0.81
0.83
0.45
3.5
3.0
2.5
1.8
2.4
0.64
1.9
7.1
3.1
4.2
5.7
6.1
10
15
20
24
18
23
11
5
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40

SESSION III

Chairman: W. G. Morrison,
Director, Design and
Development Division,
Ontario Hydro,
Toronto, Ontario

Implications of the Nuclear Control and Administration Act
J. P. Didyk,
Acting Manager,
Radioactive Waste Division,
Atomic Energy Control Board,
Ottawa, Ontario

Environmental Impact Assessment: The Port Granby Project
R. G. Dakers and
G. F. Colborne, General Manager,
Refinery Operations,
Eldorado Nuclear Ltd.,
Port Hope, Ontario

G. F. Colborne

The Disposal of High-Level Nuclear Wastes in Canada
F. K. Hare, Director,
Institute for Environmental Studies,
University of Toronto,
Toronto, Ontario

Retention of Radioactive Waste in an Active Uranium Mine
Dr. R. B. Dodds,
Morton, Dodds and Partners Ltd.,
Consulting Engineers and
Specialists, Rexdale, Ontario

Implications of the Nuclear Control and Administration Act

by

J.P. Didyk

Atomic Energy Control Board

The Atomic Energy Control Act was passed in 1946. Its principal purposes were to provide for the "control and supervision" of the domestic development, application and use of nuclear energy and to enable Canada to participate effectively in programs directed towards the achievement of measures of international control over nuclear energy. At that time the primary concern of the Canadian government in the nuclear field both domestically and internationally derived from a recognition of the importance to world peace of strategic and security aspects. Thus the Act, although designed to provide for domestic control by regulation of the nuclear fuel cycle and to permit the conduct of a number of commercial and promotional activities by Crown corporations established pursuant to its provisions, clearly emphazised strategic and security matters.

Background

As a result of a number of developments which occurred over the late 1960's and early 1970's it became apparent that a major revision of the AEC Act was required in order to enable the Board to deal effectively with the growing complexities of the nuclear field. Some of the background events leading to the preparation of Bill C-14 may be of interest to you. Starting early in 1975 the Board's public involvement emerged with startling speed. From a position of relative obscurity, AECB became an almost daily headline topic because of problems arising from poor management of radioactive wastes, health of uranium miners and intervention by nuclear objector groups. Clearly the AECB was "under the gun" for alleged poor control of past events, a criticism that was largely justified but understandable because of the Board's lack of resources to discharge its responsibilities.

A few of the milestones marking emergence of the AECB into public scrutiny are as follows:

- the finding of radium contamination in the building at 103 Church St., Toronto, early in 1975, which resulted from radium extraction work in the 1930's and

1940's led to the first major radioactivity cleanup program. AECL under contract to AECB decontaminated the building.

- during the summer of 1975, the Energy Probe group in Toronto expressed concern about the level of radioactive emissions at the boundary of some of the refinery waste dumps near Port Hope. AECB inspectors confirmed that some areas exceeded regulations; but more importantly the Board inspectors found that radioactive refinery waste had been widely used in Port Hope as grading and fill around homes and commercial premises. Radon - radon daughter problems resulted in unacceptable levels in several hundred homes. AECB, of course, was held accountable for having allowed the radioactive waste to be misused. Such criticism is theoretically correct but in practical terms, AECB was not in a position in the past to licence the Port Hope refinery operation. Nevertheless, the Board accepted responsibility for cleanup, negotiated funding from the Treasury Board and work is still going on with AECL, Chalk River being the recipient of the cleanup waste from Port Hope.

Related to the Port Hope situation are problems at the Port Granby waste management site and Deloro, Ontario which have become public issues.

- another controversial issue has been the matter of health of uranium miners and the incidence of an excess of lung cancer due to radon - radon daughter inhalation, as an occupational hazard. The Royal Commission on the Health and Safety of Workers in Mines in Ontario, chaired by Prof. James Ham (now President of University of Toronto) focussed strongly on the uranium miners' problem. The AECB submitted a brief in June 1975 and proposed certain actions such as realistic involvement in compliance with licences issued, improvement of regulatory standards, support of R&D concerning conditions such as mine radiation, dosimeter development and applications. In the interest of federal jurisdiction, which in the past had not been adequately occupied, and for which AECB was criticized by the labor unions and the press, the Board has now undertaken to fulfill its responsibilities.

- coincident with the Port Hope and the uranium miners' issues, many other areas of radioactive waste problems involving radon - radon daughter and gamma exposures were found in the 1975 to mid-1976 period. These were caused by mine waste and tailings at Uranium City, Saskatchewan, Elliot Lake, Ontario, Bancroft, Ontario, and by metallurgical slags on the outskirts of Ottawa.
- to cope with the radioactivity cleanup problem across the country, the federal Cabinet authorized the formation of a federal-provincial Task Force early in 1976. This Task Force included members from several federal departments and agencies, provincial representatives from Saskatchewan, Ontario and Quebec. It has been funded so far to the extent of $6 - $8 million with shared cost recovery arrangements with Ontario and Saskatchewan and with industry. There are several years' work yet to be done and several million dollars of cost yet to be defrayed.
- early in 1976, as the above events were developing, discussions were held between the President of the AECB and the Minister of Energy, Alastair Gillespie, concerning the basic conflict of interest perception relative to the other components of the energy ministry, upon which comments were being made by the media, the critics and the public. For example, AECB was becoming "tough" with Eldorado Nuclear (one of Mr. Gillespie's Crown Companies) on waste management. Clearly a conflict arises here between the producer and the controller. Indeed on many occasions in the media and the House of Commons this and other implied conflicts have been criticized. Basically all the components of the energy ministry are promotors or developers except for AECB, which is a controller or regulator of development. These discussions led to the Minister's concurrence that new legislation was needed and that the AECB should be removed from the energy clutch. Dr. A.T. Prince, president of AECB, was asked to prepare a Memorandum to Cabinet outlining the justification for this change together with clarification and strengthening of AECB's role. Early in 1976, this draft

memorandum led to much interdepartmental discussion and little resolution of issues as to the role of AECB. Consequently, the Privy Council Office, in July 1976, established a Task Force under the chairmanship of Dr. Maurice LeClair (now Secretary of Treasury Board) to recommend on the mandate of the AECB, its ministerial reporting channels, the resources needed and revisions to the present Act. The Task Force reported on August 3, 1976.

Government Intentions

After many drafts, Bill C-14 saw the light of day on November 24, 1977 as the Nuclear Control and Administration Act. In so doing, it served notice through certain provisions of the legislation that Canada's nuclear regulatory authority will become a major source of public information as well as a key agent to facilitate public participation in the nuclear decision-making process.

These expressed intentions are almost diametrically opposed to current practices which essentially reflect political and military requirements for confidentiality dating from the immediate post-World War II period.

Under current legislation - the Atomic Energy Control Act and Regulations - there are very severe limitations on the Board's ability to cope with the modern demand for public information and candor.

One such limitation is the statutory Oath of Fidelity and Secrecy included in the existing Act. While I think anyone can appreciate the 1946-era motivation behind creation of this binding oath, if interpreted literally it provides a pretty powerful gag for each and every staff member. I understand the Board's chief of public information has developed a noticeable twitch each time he fills an envelope with informative documents. And well he might - according to the oath, he is not supposed to communicate with or allow documents to go to any person not legally entitled to such communication. Such legal entitlement, or

lack of it, is not easily defined except in the extreme.

Another limiting factor at present is Section 26 of the Regulations, which requires the Board to withhold any information it has received in the course of its regulatory functions. The Board is thus bound to keep privy anything provided by its licensees, and although on a few occasions material has been publicly released following consultations and mutual agreement, this imposes a rather awkward mechanism on routine public information requirements.

The Board is open to criticism on its use of Section 26, not simply because it provides a statutory gag, but because it can appear to furnish a means to dodge the issue. In contemporary jargon this is known as "copping out", but fortunately, through judicious use, Section 26 has not assumed the proportions of the notorious Fifth Amendment in the U.S.

In the interest of public confidence in the nuclear regulatory authority, the Government's intention in Bill C-14 is to do away with de facto secrecy.

Information Provisions

The Nuclear Control and Administration Act as tabled before Parliament is divided into three parts. Only Part I, titled "Control of Health, Safety, Security and Environmental Aspects of Nuclear Energy", is of direct jurisdictional and administrative concern to the regulatory authority. (Part II deals with commerce and promotion, while Part III is basically devoted to punitive consequences for contravention of the Act.)

Of the 55 sections in Part I of the NCAA, seven are devoted in whole or in part to public information matters.

The key section, which in effect acts as the cornerstone for the others by setting the public relations tone for the entire Act, is Section 20 wherein the main objects of the control agency are set out in two sub-sections.

As expected, the first sub-section delineates the Board's all-important responsibility for regulation and control. However, in view of the policies and practices of the past 32 years, it may be considered quite remarkable to discover

the second sub-section which instructs the nuclear regulatory authority "to act as a source of information for the public on health, safety and environmental matters related to nuclear energy". In unequivocal terms, the Bill gives equal weight to both regulation and public information.

The regulatory agency, called the Nuclear Control Board (NCB) in the proposed legislation, is not actually exhorted to beat the nuclear drum throughout the realm. In fact, this would seriously jeopardize its neutral, objective and credible position. However, it is enjoined in the legislation from being merely a passive repository of information.

Specifically, Section 27 requires the NCB to "provide for the dissemination of information on the health, safety and environmental aspects of the development, production, use and application of nuclear energy." Following up on this is Section 32 which calls for public hearings, and Section 35 requiring the publishing of significant event notices in various media including local newpapers. The latter section is expanded upon slightly in Sub-Section 56.(2), which requires that proposed Regulations be published in advance in the Canada Gazette, thus permitting public scrutiny and comment.

Section 24 gives the Board clear authority to set up regional offices to achieve its purposes, and without doubt these centres will become important focal points for public information activities. The Board's experience over the past two years with temporary program coordination offices set up in communities where contamination problems have been encountered indicates that one has to be well prepared for a continuous public interface in these "storefront" locations.

The seventh section of the NCAA which deals specifically with public information is Section 36, which might be described as the antithesis or mirror image of the current Regulations Section 26. Section 36 of the NCAA requires the Board to make available for public inspection <u>all</u> documents in its possession except those exempt from disclosure by Regulation. The section does, however, allow anyone submitting information to the regulatory authority to request that the

material not be disclosed, but a formal Board ruling is required for the information to be labelled proprietary and thereafter not released without the submittor's permission.

Significant Details

For an audience such as this, there are probably two of the aforementioned seven sections dealing with public information which are of particular interest, and I would like to expand briefly upon these two.

The first section of interest is the one dealing with public hearings, and the second concerns the public release by the Board of information provided by another party, such as a licensee. Both these sections represent a significant departure from current practice insofar as the industry's dealings with the Board are concerned.

Section 32 provides for two types of public hearings: mandatory and discretionary. The former is clearly defined to be a requirement during the licensing process prior to the construction stage for any one of the following:

- a uranium or thorium mine, mill or processing plant;
- a nuclear reactor of power greater than one megawatt (thermal);
- a spent reactor fuel reprocessing plant;
- a radioactive waste management facility;
- a uranium enrichment plant; or,
- a heavy water plant

In other words, all major nuclear facilities will require a public hearing under Board auspices before a licence to construct is issued.

The discretionary public hearing may be used by the Board if and when it deems such action to be desirable in connection with any matter within its jurisdiction.

The mandatory public hearing, while placing a new burden on both licence applicant and regulator, is a logical extension of the public information program

the AECB has required of applicants for the past five years or so. The challenge will be to ensure that these hearings do not add unwarranted or unnecessary delay to the licensing process, yet fulfill their intended purpose as forums for both expert and public input to the licensing process, as well as vehicles for informing the people of the community concerned with the ultimate decision.

In this respect, coordination with other authorities at both the federal and provincial levels will be important, and in certain circumstances it will undoubtedly be in the best interests of all parties to conduct joint hearings rather than duplicate much of the ground covered. For legal reasons, the term "joint" may have to mean "sequential" where either chairmanship or membership of the hearing panel is specifically defined for the subjects under examination.

To a certain extent, coordination with other authorities may be facilitated by the inclusion of the principle of primacy in the Bill, wherein the Board is the lead agency in all matters nuclear, but counts heavily on other authorities to contribute to establishing standards or guidelines and provide expert advice. Provincial statutes may even be incorporated in licence conditions.

A prime area for cooperation is in environmental concerns. At the moment, the AECB is not legally responsible for anything to do with the environment. In theory, if hearings were now a Board requirement, they would not necessarily involve any environmental considerations, and a second round of hearings could be envisaged for federal works coming under the Environmental Assessment Review Process, or undertakings in provinces such as Ontario where environmental impact is required to be studied in a public forum.

Under the NCAA, however, the Board will have a clear mandate in its control of nuclear energy "to protect the environment from the hazards associated with the production, possession and use of prescribed substances." This gives it statutory encouragement to seek the expertise of and coordinate its regulatory activities with environmental authorities at both the federal and provincial levels.

With respect to discretionary hearings, the challenge will be to avoid a general slowing down of the business of the Board due to pressure from various sources to hold public hearings on a variety of relatively minor issues. At the same time, we cannot jeopardize our credibility by appearing to avoid the use of discretionary hearings.

The Board believes it can do this reasonably successfully by being quite candid and as open as possible in all its affairs, and by ensuring that hearings are held in circumstances which obviously warrant them. Undoubtedly, the establishment of the ground rules for hearings will be vitally important - the Board may make Regulations on this under Section 56 of the new Act. The purpose of hearings in general will have to be carefully defined and then a workable framework provided such that each hearing accomplishes its aims. One major area of concern is the degree to which discussion and evidence may be confined to the specific topic being examined. As you all are aware, critical groups and many intervenors will seize any opportunity to have the entire spectrum of nuclear issues considered. To counter this, while maximizing the two-way communications aspects of public hearings, such forums will have to tread a very fine line between "town-hall informal" and the legally-strict courtroom. The credibility of the regulatory authority will depend upon how well this is accomplished.

The Board's credibility, and to a certain extent the reputation of licensees should be significantly enhanced by the section dealing with release of third party information. Under this section of the statute, there will be an almost complete reversal in the policy regarding the treatment of proprietary information. It may be assumed that almost everything acquired by the Board will be made available to the public in one form or another, subject only to the formal acceptance by the Board of a request for non-disclosure, and the provisions of the Regulation covering information exempt from disclosure.

As in the case of all Regulations to be issued under the new Act, public review and comment will be facilitated by the requirement that proposed Regulations

be published in the Canada Gazette at least 60 days prior to coming into effect. It is to be expected that a Regulation limiting disclosure of information will result in considerable discussion and debate, but it is likely the following areas will be included as exempt from release in accordance with the current government policy outlined in Cabinet Directives 45 and 46:

- trade secrets;
- commercial or financial, and privileged or confidential internal memoranda and correspondence;
- personnel files, and information relating to individuals;
- information relating to safeguards practices or physical security measures;
- information from various governments or other sources received as "confidential".

If the Board has a challenge in ensuring that it is fulfilling its mandate for both control and public information through the judicious handling of third party information, the licensees have an equal challenge. They must not allow these new circumstances to detract from decades of mutual trust between regulator and licensee. Nor must they under any circumstances withhold information from the control agency in order to guard against its release. Apart from the serious consequences such action could have from the point of view of health and safety, it is something which even a neophyte public relations practitioner would counsel against.

We are in a new era of candor, an era in which the consequences of full disclosure are rarely, if ever, worse than the public discovery of duplicity or suppression of information.

Conclusion

In view of current political uncertainties, it may be some time before Bill C-14 is enacted into law. Nevertheless, it has already begun to have a significant

effect on the operations of the Board. The staff, of course, must prepare for the day when the new provisions are in place, something which cannot be done overnight. However, it is the public reaction which is most interesting.

Even though the Bill is simply an expression of intent, there are those who are now under the impression that it is the law. As a consequence, there has been a steady increase in the demands being made on our limited public information resources, and we even get mail addressed to the Nuclear Control Board. During public information meetings held by licence applicants, the Board staff present may be queried as to why a "hearing" is not being held. News media enquirers become impatient when confronted with the longstanding set of explanations as to why specific information cannot be released. And the Board regularly avoids certain types of public forums wherein its information release limitations could become a liability with respect to its credibility or perceived independence.

The enactment of this new legislation will have important ramifications for the control agency, the nuclear industry and the general public. It will, in fact, mark the opening of a new era in the peaceful uses of nuclear energy in this country, an era which should be characterized by a significantly greater awareness and understanding of the industry by the public at large.

The increased openness and visibility of the nuclear regulatory body will undoubtedly enhance the degree to which people feel confident in its control capabilities. Confidence in the regulatory process combined with the ability to make a meaningful impact thereon will surely lead to greater public acceptance of nuclear energy as a useful, modern tool.

In forcing a move, after more than three decades, from a professionally-open regulatory process to a democratically-open one, the new legislation presents both a tremendous challenge and a marvellous opportunity.

ENVIRONMENTAL IMPACT ASSESSMENT: THE PORT GRANBY PROJECT

by
G.F. Colborne
Eldorado Nuclear Limited

Eldorado Nuclear Limited operates the only uranium refinery in Canada. Eldorado began its life as Eldorado Gold Mines Ltd. in 1926 with a gold mine in Northern Manitoba. With the discovery in 1930 by Gilbert LaBine of a large highgrade deposit of pitchblende on eastern shore of Great Bear Lake in the Northwest Territories, Eldorado entered into the mining and processing of radioactive ores.

The refinery at Port Hope, Ontario began extracting radium from Port Radium ores in 1933 and except for a few small sales, stockpiled the uranium associated with the radium in the ore. The second world war disrupted the market for radium and the Port Radium mine was shut down in June 1940.

Only two years later, with the establishment of the Manhattan Project, the Government of Canada ordered Eldorado to re-open the mine and begin producing uranium. A year later the company's name was changed to Eldorado Mining and Refining Ltd. and, in January 1944, the government expropriated Eldorado making it a proprietary Federal Crown corporation. Eldorado is a financially viable proprietary Crown Corporation which owns its own assets, is not dependent upon parliamentary appropriation for funds, pays all relevant taxes or grants in lieu of taxes

and operates essentially as any other Canadian corporation. The major difference between Eldorado and other Canadian corporations is that the Federal Government is the only shareholder.

Today Eldorado employees some 1,300 people in its mining and milling complex at Uranium City, Saskatchewan, the Head Office and Research and Development Laboratories in Ottawa, the Divisional Mining Offices and Aviation Division operating out of Edmonton, Alberta and, of course, the refinery at Port Hope, Ontario. This refinery currently produces uranium dioxide (UO_2) for the CANDU reactor system, uranium hexafluoride (UF_6) for the American and European light-water reactor systems and depleted uranium metal for many non-nuclear uses.

In early 1975 as a result of feasibility studies and analysis of the UF_6 market, Eldorado determined that conditions were favourable for establishing additional UF_6 productive capacity in Canada. This decision was based upon the projected world uranium supply/demand situation, Eldorado's demonstrated competitiveness in the UF_6 conversion business and the Canadian Government policy on further processing of resources, which in the case of uranium exports is to ensure, first, that present and future, domestic requirements are protected and second that whatever uranium is exported be processed to the "most advanced form possible in Canada". At the present, UF_6

is the most advanced form of uranium that can be refined in Canada.

Environmental Assessment and Review Process

Canada's Environmental Assessment and Review Process (EARP) for Federal projects is based upon a Cabinet decision of Dec. 20, 1973, that directs federal departments and agencies to assess the environmental effects of projects they initiate or sponsor. The Environmental Assessment Panel was established on April 1, 1974, in response to this Cabinet decision, to act as a formal review agency for those projects considered by the initiating department to have potentially significant environmental impacts. One of the prime responsibilities of the Panel is to advise the Minister of Fisheries and the Environment on the acceptability of such projects.

Federal projects are considered to be those that are initiated by federal departments and agencies; those for which federal funds are solicited and those involving federal property. The definition covers those projects that may originate outside the federal government but involve a particular federal department through funding or property considerations. All federal organizations are bound by the Cabinet decision except proprietary Crown corporations and regulatory agencies which are invited, rather than directed, to participate in the process.

Briefly, the Environmental Assessment Process begins with an initial screening to identify potential adverse environmental effects.

Following this initial screening by the department or agency concerned, one of the following three decisions is possible:

(1) There are (a) no anticipated adverse environmental effects, or (b) the anticipated environmental effects are known and not considered significant.

(2) The nature and scope of potential environmental effects cannot be readily determined during preliminary screening.

(3) The anticipated adverse environmental effects are considered to be significant and the project requires a formal environmental review by the Department of Fisheries and Environment (DFE).

If the department is unable to identify the full environmental consequences through the screening process then the project is subjected to more detailed examination called the Initial Environmental Evaluation (I.E.E.). Guidelines covering such major projects as airports, nuclear power plants, pipelines are available to help in the preparation of the I.E.E.

Based on the review of the I.E.E., the department concerned then decides whether the proposed project involves significant environmental effects or not. If the effects are not considered significant, the department is responsible for implementing appropriate measures for environmental protection that have been specified, but no further reference to the Process is required.

However, if the anticipated effects are judged to be significant, the Department then submits the project to DFE for a formal review.

The submission of a project for a formal review by an Environmental Assessment Panel signals the beginning of a comprehensive process of project evaluation by a panel established specifically for that particular project. In its early stages of operation, panel members were drawn only from the staff of Environment Canada. Adjustments to the Environmental Assessment and Review Process were approved by Cabinet in February 1977 and the Chairman of the Environmental Assessment Panel may now appoint panel members from within the entire federal public service. The Minister of Fisheries and Environment may also appoint panel members from outside the federal public service.

A permanent Panel Chairman is appointed by DFE to administer Process procedures. He chairs all panels and reports to the Minister of Fisheries and the Environment on the recommendations made by panels.

A project submitted for panel review may not be carried out until a decision has been reached on panel recommendations.

Currently there are some 17-19 panels reviewing a variety of projects including power transmission lines; electricity generation;

airports; gas and oil pipelines; railway, highway and harbour facilities in addition to Eldorado's uranium refineries.

In the Eldorado project the steps involved in the environmental assessment process were as follows:

(1) The preparation of site selection guidelines.

(2) The preparation of guidelines to prepare an Environmental Impact Statement.

(3) The preparation and submission, by the proponent of the Environmental Impact Statement, to the Panel.

(4) The review of the EIS by various provincial and federal departments and the general public.

(5) The first stage of public hearings.

(6) The preparation, by the proponent, of answers to the deficiencies noted by reviewers and Panel members.

(7) The second stage of public hearings.

(8) The Panel's recommendations.

The Eldorado Project

On June 27, 1975 a preliminary meeting between representatives of the Atomic Energy Control Board, Environment Canada and Eldorado was held to discuss the application of the Environmental Review Process to our proposed expansion. At that meeting the establishment of two plants was discussed - one in Ontario and the second in Saskatchewan.

This paper will deal only with the Ontario plant - The Port Granby Project

At that meeting Eldorado, a proprietary Crown corporation and therefore exempt from the EARP, voluntarily agreed to submit the project to the process. In addition, it was decided that the Panel would contain a member of the Eldorado staff and a member of the AECB staff in addition to members from the DFE.

The first activity of the Panel was to appoint a "Working Group" to prepare site selection guidelines for Eldorado. This group consisted of six members representing the Ontario Ministry of the Environment, the Saskatchewan Ministry of the Environment, Environment Canada, the Atomic Energy Control Board and Eldorado Nuclear Limited. These guidelines were completed in October 1975 and presented to the Chairman of the Panel.

Eldorado's environmental consultants, James F. MacLaren Ltd. were authorized on July 16, 1975 to carry out an evaluation of potential sites. This study was designated as Phase I and culminated in the preparation on February 27, 1976 of a document which became later Appendix I of the EIS. This document, which compared the 16 sites, and selected the best three, was submitted to the Panel for review and comment.

In the meantime, the "Working Group", renamed the "Steering Committee", produced two additional sets of guidelines. The first was entitled "Guidelines for the Environmental Factors in Determining Recommended Site for Eldorado Nuclear Limited Plant Expansion". These were used to further evaluate the three best sites and select the preferred one for more detailed examination. The second set of guidelines were entitled "Environmental Impact Statement Guidelines for Eldorado Nuclear Limited Plant Expansion". These were finalized in October 1976 and were used by the environmental consultant to carry out the detailed evaluation of the preferred site.

The evaluation of the three best sites was designated as Phase II of the project and in June 1976 the results were compiled in a document which eventually became Appendix II of the EIS. At Eldorado's request a fourth site - the Port Granby one - was included in this study when it became possible to acquire the necessary land. This document was also submitted to the Panel for review and comment.

At the conclusion of Phase II, the Port Granby site was selected and a more detailed assessment carried out. This was designated as Phase III and the work was reported by the environmental consultants in the "Environmental Impact Assessment" in May 1977.

The Environmental Impact Statement (EIS) filed with the Panel

on June 21, 1977 consisted of all three volumes mentioned above and comprised some 1,100 pages. Some 140 copies of the EIS were distributed to provincial and federal departments and agencies, interested parties and were placed in libraries and local municipal offices in towns in the vicinity of the Port Granby site.

A 12-page abstract of the EIS was prepared and given wider circulation to the public through information centres and at the subsequent public hearings.

The EIS was also submitted for technical review to the following:

(1) Province of Ontario - all departments.

(2) Department of Fisheries and Environment - Central Ontario region.

(3) Energy, Mines and Resources.

(4) Health and Welfare Canada - Radiation Protection Bureau.

These technical reviews critiqued the EIS indicating weaknesses and deficiencies. These reviews, varying in length from 30 to 70 pages, were published and made available to all participants at the hearings.

The Public Information Programme

The formal public information programme or "Public Communications Programme" as we prefer to call it, began on January 7, 1977 with the simultaneous opening of Information Centres in both Port Hope and Bowmanville. These centres were manned by staff from the

Port Hope Refinery on a rotational basis for the first four or five months and then by retired Eldorado employees for the balance of the time. The one in Port Hope remained open for 10 months while the Bowmanville one remained open for 15 months.

During the January to August period in 1977 about 1,400 people visited the centres. This did not include the many school children who arrived singly, in pairs and clusters, to watch the movies or test the density models or scintillometers.

Senior personnel from the Port Hope plant gave slide illustrated talks to service clubs, school classes, special interest groups, etc., throughout the first half of 1977. Eldorado personnel also visited occupants of houses in the immediate vicinity of the site to inform them about the project and to discuss any concerns that they many have had.

A number of advertisements were placed in area newspapers and an illustrated brochure was mailed directly to some 20,000 homes in the area.

Public Hearings

During the Spring and Summer of 1977 a number of discussions were held between representatives of Eldorado, Ontario Ministry of the Environment and Environment Canada regarding the format to be followed in the Public Hearings.

The end result was the public release on Sept. 6, 1977, of the Panel's announcement that the Public Hearings would be held in Bowmanville on Sept. 27, 28 and 29 and then move to Newcastle for Oct. 4, 5 and 6. This release was accompanied by large advertisements in local newspapers and letters addressed to residents of the nearby communities.

Presentations at these hearings were made by individuals, representatives of both federal and provincial government agencies and representatives of special interest groups. The following anti-nuclear groups were represented:

CCNR -Canadian Coalition for Nuclear Responsibility

PANDA -People Against Nuclear Development Anywhere

-Greenpeace Foundation

CANTDU -

-Energy Probe

OPEN -Ontario Peoples Energy Network

SEAP -Save the Environment from Atomic Pollution

The preponderance of presentations were definitely against the company proposal. This was probably a case of the vocal minority and the silent majority. The Town of Newcastle has a population of about 28,000 people - the vast majority of whom did not attend the hearings or make presentations. A professionally conducted survey of the area

revealed that close to 40% of those aware of the project felt that it was "basically a good idea". Another 40% were unsure while the remainder felt it was "basically a bad idea".

At the conclusion of this phase of the hearings the Panel began deliberations on the rather voluminous briefs presented orally and in writing.

On November 26, 1977 the Panel issued, to all who had taken part in the proceedings or had expressed interest in the matter, a list of items that the Panel considered to be information deficiencies or areas requiring further clarification following Phase I of the Hearings. This list comprised about 22 pages and contained about 67 individual items.

Eldorado and its environmental consultants attempted to answer the concerns expressed at the Hearings or contained in the above publications and on December 13, 1977 issued a 192 page volume entitled "Supplement to the Environmental Impact Assessment - the Port Granby Project - Responses to Phase I: Environmental Hearings". A separate 20 page volume on responses to the questions raised regarding waste management was issued at the same time

On January 4, 1978 the Panel issued to "all interested parties" the notice that the second phase of the Hearings would be held on January 24, 25, 26 and February 7, 8 and 9, 1978 in Bowmanville. In

this release they identified nine separate issues that would be discussed and scheduled specific times for each.

The format of the Phase II hearings was changed somewhat and each day's schedule included a list of lead speaker(s), listed speakers, technical witnesses and agencies present. The role of the technical witnesses, as defined by the Panel was "to aid in publicly providing the knowledge base which all participants, and particularly the Panel, can use in attempting to understand the issue and reach conclusions".

The participants and speakers at the Phase II hearings were, for the most part the same groups and individuals who participated at the first stage. Eldorado was represented by the same people as in Phase I but made more use of consultants to address specific issues that were raised.

The hearings ended on February 10, 1978 and on February 27th the Panel issued a press release stating that "the refinery itself and the refining processes could be environmentally acceptable on an appropriate site if a number of conditions were met. The Port Granby site, however, was not found acceptable by the Panel.

The Panel was concerned about the potential environmental effects of the project as well as its social impact on the Port Granby community. The Panel was particularly concerned about the intrusion

of the refinery as an industrial use into an area where the present and long-term character is rural and favours agriculture.

The Panel also rejected Port Granby as the site for the waste management facility."

The full report of the Panel was issued on May 12, 1978 and essentially elaborated upon the above conclusions.

We were, of course, very disappointed in the Panel's recommendation that we not be allowed to construct the refinery on the Port Granby site. The central issue was clearly that of land use planning. We would require about seventy acres for the plant site and waste storage area and had undertaken to preserve the agricultural productivity of the adjoining buffer zone. The seventy acres had been used to grow tobacco for many years.

At the present time the Minister of State for the Environment has accepted the Panel's recommendations. To date there has been no formal decision from the Minister of Energy, Mines and Resources, to whom Eldorado reports.

The complete process, from the day in 1975 when we first approached the Panel chairman at that time, until the present, has taken three years and has cost Eldorado in excess of one million dollars - and we don't yet have an approved site.

Current Plans

Eldorado is currently re-examining three previously identified sites in the Port Hope and Sudbury regions and along the north shore of Lake Huron. Preliminary environmental assessments of all three are underway and a firm decision on the preferred site is expected by the end of June. At that time the assessment of the two rejected sites will be terminated and work intensified on the preferred site.

The present schedule calls for the submission of an EIS on the preferred site by September 1978, public hearings completed and a decision made by the end of this year. This will enable Eldorado to begin construction in Spring 1979 and commission the new plant in late 1981.

Any delay in plant start-up beyond 1981 may well mean that producers in other parts of the world would be able to increase their productive capacity to meet the UF_6 demand.

Recommendations or Suggestions

(1) Eldorado's understanding is that the site at Port Granby was rejected mainly because of the Panel's concern about the intrusion of industrial activity into an agricultural and rural setting.

Whether or not this is a valid reason for site rejection, it was not a major criterion in the guidelines developed and approved

for Eldorado's proposed refinery

(2) Throughout the public hearings, the majority of the speakers and the audience were definitely against the project. We would recommend to any department or agency going through the EARP process to ensure that the people and organizations favouring the project be as visible as those opposed to it. A good public information programme can determine the supporters and educate them to make meaningful contributions at the hearings.

(3) When technical witnesses are known to have biased opinions on a given subject (e.g. nuclear energy), the Panel has an obligation to ensure that the other side of the argument is also presented.

(4) There must be found a way to prepare guidelines, carry out environmental assessments, hold public hearings and give a decision in less than three years and at a cost considerably less than one million dollars. If this cannot be done it will surely inhibit expansion by departments and agencies subject to the EARP process.

THE DISPOSAL OF HIGH-LEVEL NUCLEAR WASTES IN CANADA

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Canadian reactors — in practice Ontario reactors — are currently producing spent fuel at the rate of about 400 tonnes per annum, (T y^{-1}) or about 130 T per 1,000 MWe of electric power generated. An aggregate of near 2,000 T is held in water-filled bays at generating stations. If current plans to expand CANDU once-through stations to 75,000 MWe by the year 2000 are realised (now doubtful), the accumulation rate by that year will be 10,000 T Y^{-1}, and the aggregate storage will be 50,000 T. This corresponds to a storage space (in water-filled bays) of 10 x 8 x 1,250 m, or about 100,000 m^3. This irradiated fuel contains intensely radioactive fission products (such as Sr-90 and Cs-137) and actinides (e.g., Pu-239, Am-241). It can be retained in interim storage for a few decades. During this time a decision must be taken whether or not to reprocess the fuel to extract Pu-239. If this is done, highly radioactive liquid wastes will be produced, for which immobilization technology (ceramic or vitrified) will be needed before disposal is possible. In either case, the irradiated fuel (suitably clad) or immobilized reprocessing wastes will need to be emplaced in a geological repository, preferably beginning about 1995. An Ontario site is inevitable, and a quartz-poor igneous rock in a seismically stable

*Acknowledgements: I am very much indebted to Dr. A.M. Aikin and Dr. J.M. Harrison, my colleagues in the federal study group on nuclear waste disposal, for many critical comments and suggestions on this paper. I also owe them a great deal for the way in which they taught me the subject in the summer of 1977. But the paper is my own responsibility, and may well not represent their views. Needless to say, it also has no official status, though Dr. O.J.C. Runnalls, Senior Advisor, Uranium & Nuclear Energy, Department of Energy, Mines and Resources, has been good enough to criticize the text.

are preferred. Such a repository offers good prospects of safe confinement of the radionuclides until they have decayed into harmless forms.

Introduction

The disposal of high-level nuclear waste from power reactors has become one of the most visible of all waste management problems. Opponents of nuclear power announce dramatically that no solution to the problem is at hand, and predict that none will ever be found. From this pessimistic view they draw the conclusion that power reactors should not be allowed to multiply, or even that they should be phased out. Many Canadians are obviously influenced by such views, as are Americans and Europeans. In more than one country the very existence of a nuclear option has been questioned on the grounds that the disposal problem may be insoluble. We should not bequeath to future generations, it is argued, deadly wastes that may well outlive the species.

It is indeed true that no technical long-term solution has been demonstrated for irradiated fuel — for the simple reason that none has been sought until recently. The nuclear engineers saw this problem as being technically easy, by comparison with the design and operation of nuclear fuel cycles. Moreover the possibility existed that the plutonium-239 and uranium-235 remaining in the fuel could some day be extracted, and recycled through reactors to produce further power. The fuel could remain in storage until this possibility could be adequately assessed. Then, and only then, would it be reasonable to talk about wastes. In the meantime the word "disposal" was taboo. If anything was to be disposed of, it would be immobilized high-level liquid wastes from processing plants. And there would be no need for such plants in Canada before the twenty-first century; the technology

of processing could not be brought to commercial readiness much sooner.

It is easy to criticize the profession for this omission, but I shall not do so. Canada's nuclear industry came into being, in the wake of World War II, with a mandate to create a safe, reliable system of power generation and to develop other applications of nuclear technology. It has succeeded in both. We have our own system of reactors, and we have pioneered in some of the most useful medical and industrial uses of radionuclides. In this field, at least, we have achieved a high degree of technological autonomy. Our engineers and scientists are respected world-wide. Their level of technical competence has been such that one must take seriously their opinion that waste disposal will be readily mastered. Bennett Lewis argues, in fact, that existing methods of interim storage can evolve into permanent, monitored surface retention. I was pulled into this debate, as an environmental scientist, by the federal Deputy-Minister of Energy, Mines and Resources. I had little prior knowledge of the problem. Bolstered up, however, by two more competent colleagues, I have arrived at some conclusions.

A solution to the problem of nuclear waste disposal, I believe, must be <u>seen</u> to be a solution by the public at large. Their political representatives must be able to assure themselves that all will be well, as far as one can currently judge. Decisions of this magnitude must be taken politically (in the best sense of that word), and not by technologists. So there has to be a political debate, which should have taken place before the first power reactors came on stream. This did not happen because of the common political habit of taking decisions behind closed doors. The technical community did indeed consider the question of waste disposal. But there was little public interest or attention — and no firm political decision.

Instead the debate is happening now, when it is too late to avoid waste disposal, and when uneasiness has been created in the public mind. Activist organizations are doing their best to challenge not only the safety of the nuclear industry, but even its survival. One should welcome the debate, late though it now seems. In this country, at least, there is still time to correct past mistakes. I hope that the outcome will be the political decisions needed. These must cover the questions: do we process our irradiated CANDU fuel? Do we go on to other and more advanced fuel cycles, as the engineers suggest? And in either case, what should be our method of disposal of the resulting wastes? The answers to these questions depend, not only on political will, but on research and development that will take a long time. So they will not come easily or quickly. They will not come at all unless we decide to look for them.

The Wastes

A CANDU reactor derives its heat from (i) the fission of uranium-235, which is 0.71 per cent of the natural uranium in the oxide fuel (UO_2); and (ii) from the fission of plutonium-239, formed by neutron absorption by the much more abundant uranium-238, after radioactive decay. After a year or so in the reactor the fuel rods are removed, because they have become inefficient in the use of the available neutrons. On removal from the reactors the rods contain

(i) small amounts of unconsumed U-235* and Pu-239, both of which are fissile, and hence capable of being reintroduced into a reactor if extracted from the fuel by processing;

(ii) much unconsumed U-238, which is still fertile, i.e., still capable of being converted to fissile Pu-239 by neutron absorption and subsequent decay;

*in CANDU fuel, though not in light water reactors, the amount of U-235 (about 0.2%) is too small to be worth recovering.

(iii) other α-emitting heavy elements, called actinides, which are formed from U-238 by neutron absorption. These include isotopes of neptunium, plutonium, americium and curium. Many have long half-lives (e.g. Pu-239, 24.4×10^3 y; Np-237, 2.1×10^6 y). Isolation is required for hundreds of millennia if the complete decay of Pu-239 is demanded. If ore-body equivalent radiation is required, then 10,000 to 15,000 years should suffice.

(iv) fission products, which are elements, usually radioactive, formed by splitting U-235 and Pu-239. These include mainly nuclides from the middle of the atomic table, principally from krypton-85 up to the rare earths, with strontium-90 a well-known example. The fission products are mostly short-lived, and are usually emitters of β and γ radiation. Others have longer half-lives, notably Sr-90 (27.7y) and Cs-137 (30.0y). Iodine-129 and technetium-99 have half-lives of 1.7×10^7 y and 2.1×10^6 y respectively. On the average, fission product activity decays very rapidly, but significant activity persists for many decades. Isolation for about 600 years is ordinarily recommended.

(v) the zirconium-alloy cladding of the rods, which is also made radioactive in the reactor.

Initial management consists of storing the rods under water for some years after removal from the reactor, to absorb the radiation and heat, and to permit the shorter-lived nuclides to decay. CANDU reactors produce about 130 tonnes of irradiated fuel per 1,000 MWe-year. Nearly 2,000 tonnes are in storage at Pickering GS and Bruce Nuclear Power Development. The rods are intensely radioactive, but the water provides an effective shield, and is filtered to remove fission products that may escape from imperfections

in the claddings.

The water-filled bays at the generating stations have limited capacities, and it will be necessary to move the rods to interim-storage facilities by about the mid-1980's. Some technical opinion favours transporting the rods to a central interim storage facility, where water-filled bays of different design could continue to house the cooling fuel for some decades. AECL has been experimenting with concrete canisters disposed on the surface. The object is (a) to contain the fuel while it cools and loses some radioactivity, (b) to isolate it from all living organisms, and (c) to retain it in recoverable form for subsequent processing or disposal.

The amount of such fuel that will thus accumulate at Canadian generating stations, or at interim storage sites, clearly depends on the rate at which new power generating facilities are commissioned. It was estimated in 1976 by the federal Department of Energy, Mines and Resources that by 2000 A.D. the probable installed capacity in Canada would be 75,000 MWe. If realized, this installation would correspond to an annual accumulation of 10,000 tonnes of irradiated fuel, added to an inventory of about 50,000 tonnes by the year 2000 (Aikin, Harrison & Hare, 1977).

This estimate of installed power is very tentative, and is disputed by those who would prefer to see Canada tread the so-called soft energy path. Uffen (1977), much influenced by Flowers (1976), argues that installed capacity should be held at about 20,000 MWe until "fully satisfactory" waste-disposal methods have been demonstrated.

My own view is that the immediate task is to carry out the research and development needed to make possible such disposal. I am confident enough that this can be done successfully, at least as regards irradiated fuel, to see no reason to delay future commissioning of CANDU reactors. But, and it

is a vital "but," I would change this view if research and development were delayed. Even if we were to stop all future development the need to dispose of the wastes would remain. Hence we must go ahead with disposal technology, and without any delay.

In passing I should note that large volumes of lower level waste are produced in reactor operation. These reactor wastes are bulky, but can usually be reduced in volume by incineration or compression. They may contain fission products or actinides, but their total radioactivity is less than 1 per cent of the aggregate produced. Certain liquid or volatile wastes — such as tritium, argon-41 and krypton-85 — are allowed to escape in small quantities, and are dissipated in the atmosphere or water bodies. Such escape is monitored and regulated. In this brief paper I shall not deal with either these fluid emissions or the reactor wastes. Overwhelmingly, then, the radioactivity is contained in the irradiated fuel. The big question is clearly: what shall we do with it?

Fuel processing and waste form

Though the CANDU technology was originally conceived as a "once-through" cycle, it is technically feasible to process the irradiated fuel in order to extract the plutonium-239. Much technical opinion in Canada has favoured the development of advanced cycles using the Pu-239 — plutonium recycle, for example, or a thorium cycle. Th-232 is fertile, like U-238. It can be changed, after some decays, to U-233, which is fissile. Fuel processing is a necessary precondition of such advanced cycles, unless one proposes to import the necessary start-up materials.

Although plutonium-extraction is an old established technique, developed for military purposes, and although it has been done in Canada — at Chalk River — a commercially-feasible technology has not been developed

here. It will certainly take many years to develop. Moreover it will be costly, since CANDU fuel contains less fissile material than does the fuel removed from U.S. light water reactors. We have no certain picture of Canada's long-term uranium reserves, although prospects are highly encouraging. Hence fuel processing is at present of questionable economic competitiveness, and the advanced fuel cycles remain uncertain creatures of an uncertain future. Some Canadians are strongly opposed to processing on the grounds that separated plutonium, uranium-235* or -233 are capable of being diverted for military or terrorist purposes. Even the Aikin-Harrison-Hare report (1977), much criticized by anti-nuclear groups, says that "a significant quantity of separated plutonium or other fissile material in pure form should not be allowed to exist in Canada."

The relevant question in this paper, however, is this: what effect would processing have on the waste disposal problem? Will it help or hinder?

Present processing methods involve the solution of fuel in nitric acid. After removal of the useful fissile nuclides, one is left with an acid broth containing the fission products and the other actinides. Large volumes of such high-level liquid wastes, neutralized and concentrated, are currently stored in the U.S., the U.K. and in western Europe. Some escapes have occurred from tankage and serious mistakes have been made in solidification of the wastes that makes extraction for disposal difficult. It can thus be argued that Canada should avoid a technology that might land us in the same predicament. To quote the Aikin-Harrison-Hare report again, "no commercial fuel processing plant should be approved in Canada until, inter alia, fully satisfactory methods for dealing with the associated radioactive wastes have been developed." As these authors stress, such methods call for a prolonged research and development programme.

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* processing of CANDU fuel will not produce separated U-235.

These methods will require the immobilization of the radionuclides in glass or ceramic form, with further cladding. These waste forms require to be developed so as to minimize the rate of migration of radionuclides, and their subsequent solution or suspension in circulating ground-waters. They also need to be heat and radiation resistant. Work along these lines has been done in many countries, as well as at Chalk River, but much remains to be learned.

Processing wastes, once immobilized, will contain less plutonium and uranium than the irradiated fuel, and will thus have less long-lived radioactivity. But they will still contain all the fission products, and the other actinides. One incurs the problem of handling the high-level liquid wastes (and of some higher occupational exposures and escape of volatiles to the atmosphere) without a large gain. Certainly processing is not necessary for waste disposal. Nor is the treatment of the wastes to remove some of the other actinides.

If Canada decides instead to dispose of irradiated fuel from CANDU reactors, it will still be necessary to consider the form in which it will be disposed of. After spending some decades in interim storage the fuel cladding, and the integrity of the fuel itself, cannot be relied on without question. Hence a programme of research and development is also needed to answer these questions. This has only recently been seen as a possibility by the industry, and work is in its infancy. But it should present no insuperable difficulties.

The decision as to processing should certainly be taken on other grounds than the feasibility of waste disposal. The critical issues include the performance, safety and economic viability of advanced fuel cycles; the risks involved in the separation and storage of fissile nuclides; and the

attractiveness (or otherwise) of alternatives. These are beyond my present competence and scope. Again they require political decision, after technological advice. And at present Canadian public opinion is not well enough informed about the issues for a proper debate to take place. Such debate will require, inter alia, the outcome of research and development programmes not yet launched.

Disposal

At some future date, then — perhaps in the middle or late 1990's, perhaps later — the country will have taken these decisions, and we shall be in a position to dispose of the accumulating inventory of high-level nuclear wastes. These will be either irradiated fuel, suitably treated and clad, or immobilized wastes from fuel processing plants, in vitreous or ceramic form. If disposal begins before the year 2000, it will almost certainly be of fuel, because it is virtually certain that no advanced fuel cycle reactors will be on stream in this century — though present reactors could use some recycled fuel, and it is conceivable that a decision to process will have been taken.

I and my colleagues of the federal study group on the management of Canada's nuclear wastes concluded that the above uncertainty makes little difference to the choice of disposal methods. In both cases the objective must be to protect this and all subsequent generations of human beings against the hazards of ionizing radiation from the wastes, whether they be fuel or processing wastes. In addition one must try to protect other organisms, partly from self-interest, but also (let me add personally) because some of us think that man has a duty to protect all nature to the best of his ability — given his need to live. These objectives are the same as those of all other participants in this Conference. It may be that some of

us are handling materials more dangerous than the radionuclides. But a vocal section of the public perceives nuclear waste disposal as being especially difficult and crucial. So we must meet high standards.

Disposal should mean, we suggest, the putting away of the wastes in as safe a place as possible — a repository — with no intention of recovering it ourselves, or of letting our descendants recover it. Bennett Lewis argues that we ought to leave the recovery option open, in case something goes wrong, or in case some useful rôle opens up for a particular nuclide. We feel that this would be a burden for future generations. In any case, one can doubt the long-term stability of human institutions, and even of scientific learning. So we opt for non-recoverable disposal.

Such a repository must meet stringent requirements. It must

- contain the wastes successfully
- isolate them from contact with living organisms
- disperse the heat produced
- be remote from usable natural resources

We considered a variety of options. We looked, for example, at disposal on or beneath the ocean floor. This has many advantages. But we rejected it as an immediate solution because we were unsure about the technological feasibility, and because the ocean floor is under international jurisdiction: hence quick decisions would be hard to come by. We regarded disposal in the Greenland and Antarctic ice sheets as unacceptable for related reasons. Disposal to space by rocket expulsion struck us as too dangerous. Permanent surface storage seemed to us to be too insecure. So we opted for deep, geological disposal.

We argued for the construction of an engineered repository in Ontario (where most of the wastes will be produced into the indefinite future). And

we chose felspar-rich, quartz-poor igneous intrusive rocks in plutons about 5 kilometres across — of which the Geological Survey of Canada says there are more than 1800 in Ontario, in a belt from the Manitoba border to the Thousand Islands. We also considered salt deposits, but the readily accessible beds have been extensively worked, and are likely to be in use for centuries.

The repository, we argued, should be at a depth of 800 to 1000 metres, where open fractures or fissures would be unlikely, and where ground-water circulation would be absent or very slow. We were satisfied that such plutons could be found, and that two of them could be identified for underground exploration and testing by 1983. They should be tested for the following properties:

- structural strength and integrity, even under strong irradiation and heating;
- ability to conduct away the large amount of heat produced by the wastes, to prevent temperatures from rising above some chosen upper limit, given a suitable spacing of the wastes;
- behaviour of nearby groundwater systems, and the overall hydrology of the drainage basin concerned;
- geochemistry of the rock, to ensure strong sorption of radionuclides that may be dissolved or suspended in such groundwater as does penetrate the repository. There is a technical consensus that this is the key to successful containment, and is the basis for our preference for felspathic, quartz-poor rocks;
- ecosystem function in the drainage basin above, which will need long-term monitoring as well as base-line evaluation prior to waste emplacement.

We recommended that a site remote from earthquake epicentres be selected, though such catastrophes have surprisingly little effect on underground structures. This would eliminate, for example, the St. Lawrence Valley and the far south-eastern part of Ontario. The highly stable part of the country lies west of a line from Sault Ste. Marie to James Bay. And that means Northern Ontario, if we eliminate the other provinces. We estimated, incidentally, that a full decade of observation, experiment and testing would be required before the repository could become operational — perhaps between 1995 and 2000.

In the short time available I cannot detail our arguments in favour of the above recommendation. They can be and have been hotly disputed (for example, see CCNR, 1978). I suggest that they represent the best course for this country for the disposal of wastes that cannot be avoided, and cannot be ignored.

Conclusion

Uncertainty and alarmist tactics have made it virtually impossible for Canadians to approach the discussion of this issue in a realistic frame of mind. Lack of political leadership has also been conspicuous. As it is, many people reject the siting of a repository near their house, or their summer home — and I have heard of no Indian band that wants it under their hunting grounds or traplines. Yet nearly everyone insists on cheap electric power — and the Province has committed itself, by Ontario Hydro's recent contractual purchase of uranium, to the nuclear option.

My sympathies in this are for the layman. Which expert, or which non-expert can he trust? I cannot claim to be an expert, yet I've expressed strong opinions today, because I've been able to study the evidence, and arrive at conclusions. Few other laymen have the chance to do this, and

they are scared by people who tell them of the dangers that waste disposal may bring. For such people I have only this assurance: that not disposing of the wastes will be much more dangerous than disposing of them. And actually I believe that the latter can be done with little risk (though not perfect safety, because that doesn't exist).

How do we persuade the public to accept this? I have no firm suggestion — except that this is a matter for courageous political leadership, which Canada has conspicuously lacked. I remember a remark attributed to D'Arcy McKeough. He is reported to have said: "Tell us what to do, don't tell us how: we're experts in that!" I profoundly hope he's right. You can't have power reactors without producing wastes. You can't in all conscience go on producing the wastes without a plan to dispose of them. You can't have a repository unless you conduct a prolonged period of research and development that should have started long ago. And you can't even start such research without public acceptance. That is what our leaders, federal and provincial, will have to contrive somehow — with the help of concerned citizens like ourselves.

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RETENTION OF RADIOACTIVE WASTES IN AN ACTIVE URANIUM MINE

by

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1. INTRODUCTION

This paper describes the tailings and waste water management of a Uranium Mine located near Bancroft, Ontario between Algonquin Park and Lake Ontario as shown on the Key Plan in Figure 1. The mine began operation in April, 1957 as Faraday Mines Limited and ceased operations in June, 1964. The mine was re-opened in the summer of 1976 as Madawaska Mines Limited.

The mine site is located in a predominantly tourist recreation area and is therefore extremely sensitive to hazardous waste emissions into the environment.

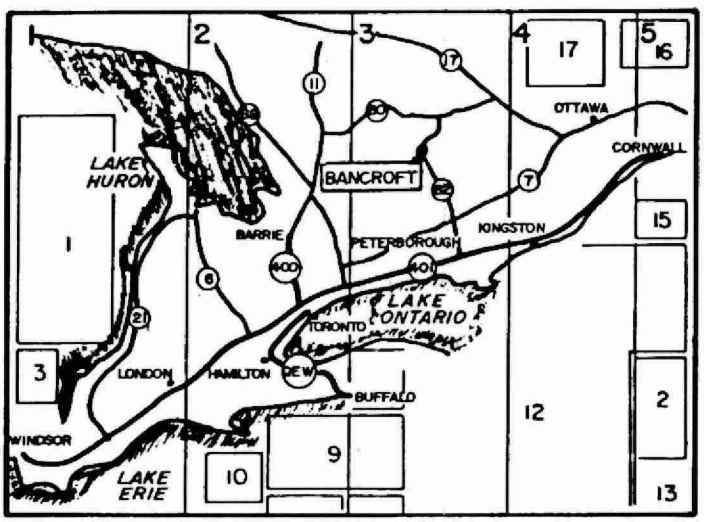


FIGURE 1

2. RADIOACTIVE WASTES

Wastes from ore processing in the present state-of-the-art of uranium mining include wash water, sands and waste solids and various process liquors. Customarily these liquid wastes are stored in tailings ponds or lagoons where the volume of waste is reduced by evaporation and seepage of the liquid portions.

Only uranium is recovered from the ore and the processed waste includes all of the radioactive daughters in varying amounts. Radium, at the moment, has not sufficient value to warrant recovery and more than 98% of the solid radium in the ore is discharged with the solid wastes.

2. RADIOACTIVE WASTES (cont'd)

The decay chain of the major natural isotope of uranium U238, shown on Figure 2, encompasses radioactive isotopes of eight elements. If the minor uranium isotope U235 and natural thorium Th232, decay chains were to be considered then radioisotopes of another four elements would be included. Fortunately, it is not necessary to analyse waste streams for all these elements and their radioactive isotopes in order to limit radiation hazard. The four radionuclides Th230, Th234, Ra226 and Pb210 present the major hazard from the U238 chain. U235 comprises only 0.7% of the natural abundance of uranium isotopes and the decay chain has no radiosotope as hazardous as Ra226. Its daughter products, therefore, do not significantly increase the radiation health hazard of the U238 chain. Thus, only the element Ra226, Th234, Th230 and Pb210 need to be monitored. Ra226 and Th230 are bone seeking alpha emitters with half-lives of 1,620 and 80,000 years respectively. Pb210 is a beta emitter which concentrates in the kidney and has a half-life of 22 years.

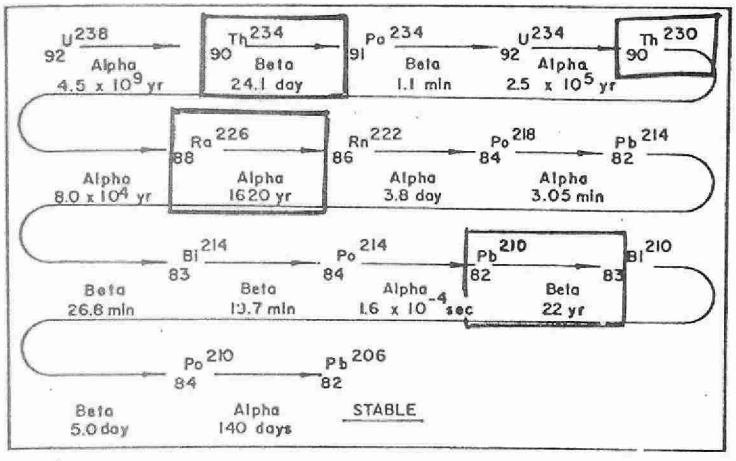


FIGURE 2

Of particular concern is the amount of dissolved Ra226 that may seep into nearby natural bodies of water that are used for recreational purposes or contain biota. Currently the concentration of dissolved Ra226 that may be allowed to seep into the environment is controlled by the following codes:-

1. "Authorized Levels of Substance" and "Authorized Levels of pH", Schedule 1 of the Metal Mining Liquid Effluent Regulations and Guidelines, Report EPS1-WP-77-1, Water Pollution Control Directorate, Fisheries and Environment Canada.

2. RADIOACTIVE WASTES (cont'd)

2. "Guidelines and Criteria for Water Quality Management in Ontario" issued in July 1974 by the Ontario Ministry of the Environment.

The regulations for the Fisheries and Environment Canada are summarized below for dissolved Ra226:-

Objectives

Max. acceptable monthly arithmetic mean conc.	Max. acceptable conc. in a composite sample	Max. acceptable conc. in a grab sample
10.0 pCi/l	20.0 pCi/l	30.0 pCi/l

Frequency of Sampling

At least weekly if conc. is equal to or greater than	At least every two weeks if conc. is equal to or greater than	At least monthly if conc. is equal to or greater than
10.0 pCi/l	5.0 pCi/l	2.5 pCi/l

3. GEOLOGY OF SITE

The general layout of the tailings disposal site is shown in Figure 3. The surficial geology of the site principally consists of a Precambrian rock knobby hills with a light soil cover and hardwood tree growth. The bedrock depressions have been filled with alluvial sands and gravels to depths in excess of 31 meters (100 feet).

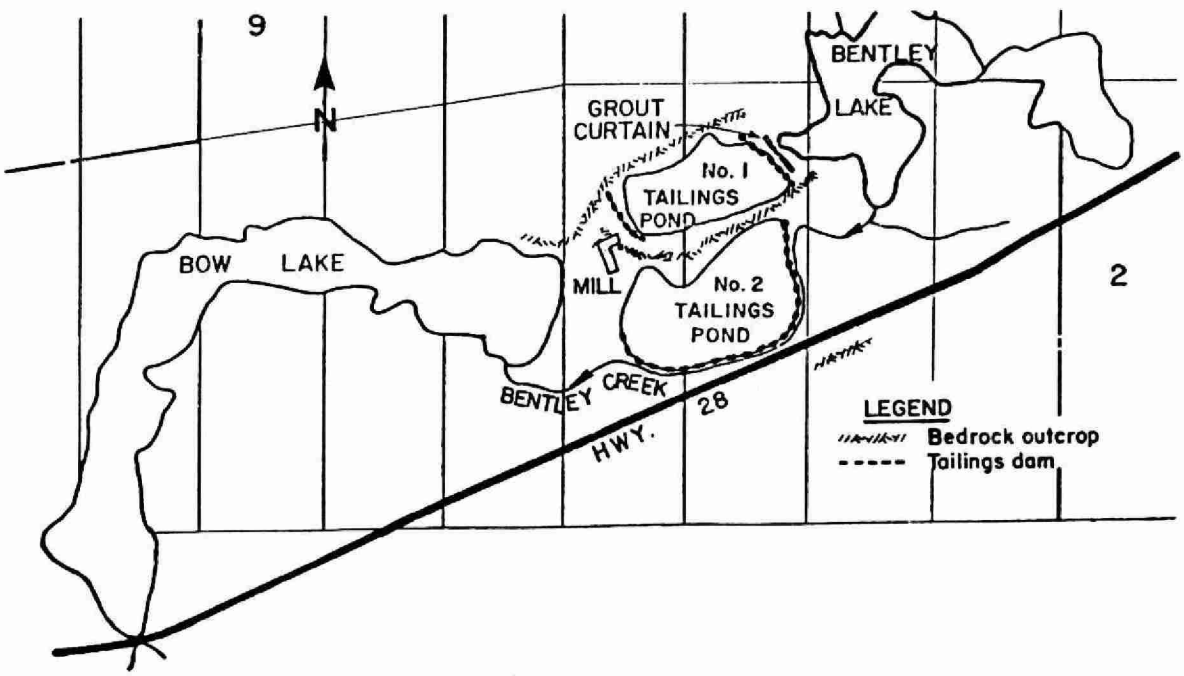


FIGURE 3

3. GEOLOGY OF SITE (cont'd)

The bedrock is part of the so-called Grenville Province of the Canadian Precambrian Shield which comprises rocks of middle to lake Precambrian age. The rocks consist of an extremely varied series of metormorphosed plutonics and metasediments with a minor incidence of unmetamorphosed late Precambrian intrusives. The plutons range from acidic granites and cyanite rocks to basic nepheline gneisses, diorites, gabbros and amphibolites.

The natural overburden within the natural declevities of the bedrock surface comprise late-glacial or post-glacial fluvial deposits of sands and gravels. No clays or other impervious materials were intersected in any of the exploration programs carried out by our firm. These deep granular deposits exist adjacent to the east end of Bow Lake extending eastward beneath the area referred to as Tailings Pond No. 2 in Figure 3.

The sediments do not appear to interconnect directly with Bentley Lake except by a relatively shallow narrow declevity in the rock between Bentley Lake and the east end of Tailings Pond No. 2. This narrow depression is followed by the present channel of Bentley Creek.

Pressure tests carried out in shallow bedrock core holes on various parts of the site indicate that the bedrock is relatively tight. This is confirmed by the fact that approximately 45 km (26 miles) of subsurface mine works produce only 408 litres/min (90 IGPM) of groundwater flow.

4. MINE OPERATIONS

The mine uses an acid leaching process to remove the uranium. A simplified flow sheet is shown in Figure 4.

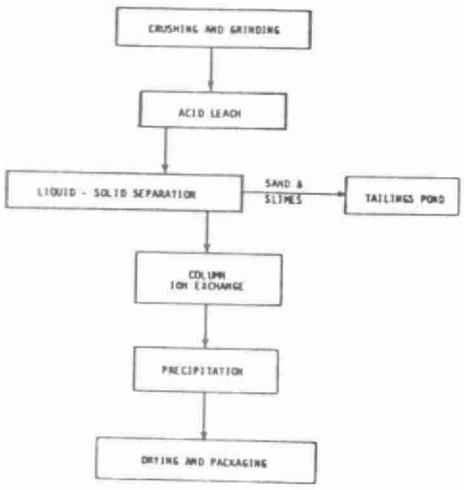


FIGURE 4

4. MINE OPERATIONS (cont'd)

4.1 Previous Operation

Upon start-up in April, 1957 the mine waste water and tailings were initially deposited in a disposal area formed by dams made of mine wastes on three sides and rock outcrop on the fourth side, enclosing a depression filled with water and muskeg with a sand island in the centre. The system for handling the tailings and mine water at that time is shown on Figure 5. This area is presently referred to as Tailings Pond No. 2. The normal drainage from Bentley Lake to Bow Lake went through Bentley Creek which passes through this depression. The Creek was rerouted outside the tailings dam adjacent to Highway 28 and is presently in this location. The use of the area for tailings disposal was terminated in June 1962 with a maximum depth of tailings in the order of 12.2 metres (40 feet)

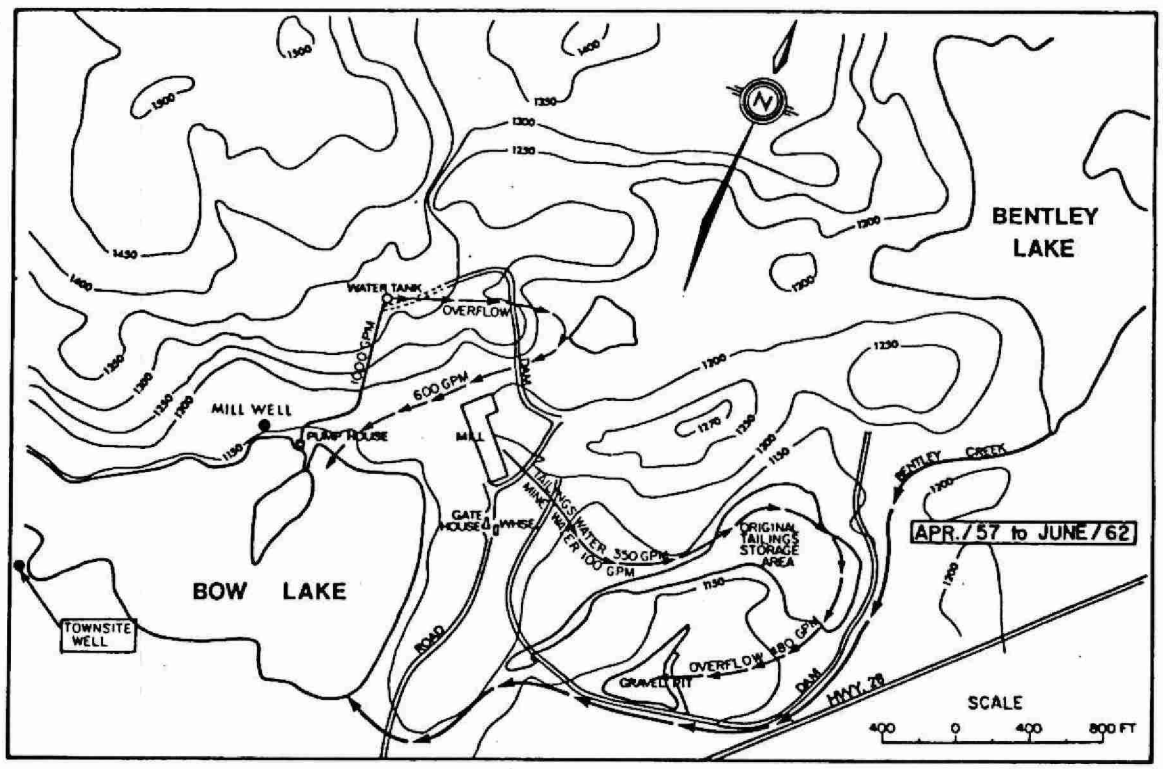


FIGURE 5

4. MINE OPERATIONS (cont'd)

Thereafter the tailings were deposited in a second natural bedrock depression to the immediate north which is filled with a deep alluvium on the north-east side adjacent to Bentley Lake. The system for handling the tailings and mine water during this period is shown on Figure 6. This area is referred to as Tailings Pond No. 1. It was used until the closing of the mine in 1964 with the approximate depth of 6.1 meters (20 feet) of tailings. Mine water was pumped directly into Tailings Pond No. 2 at a rate of 410 litres/min (90 IGPM) from 1967 until re-opening of the mine in 1976.

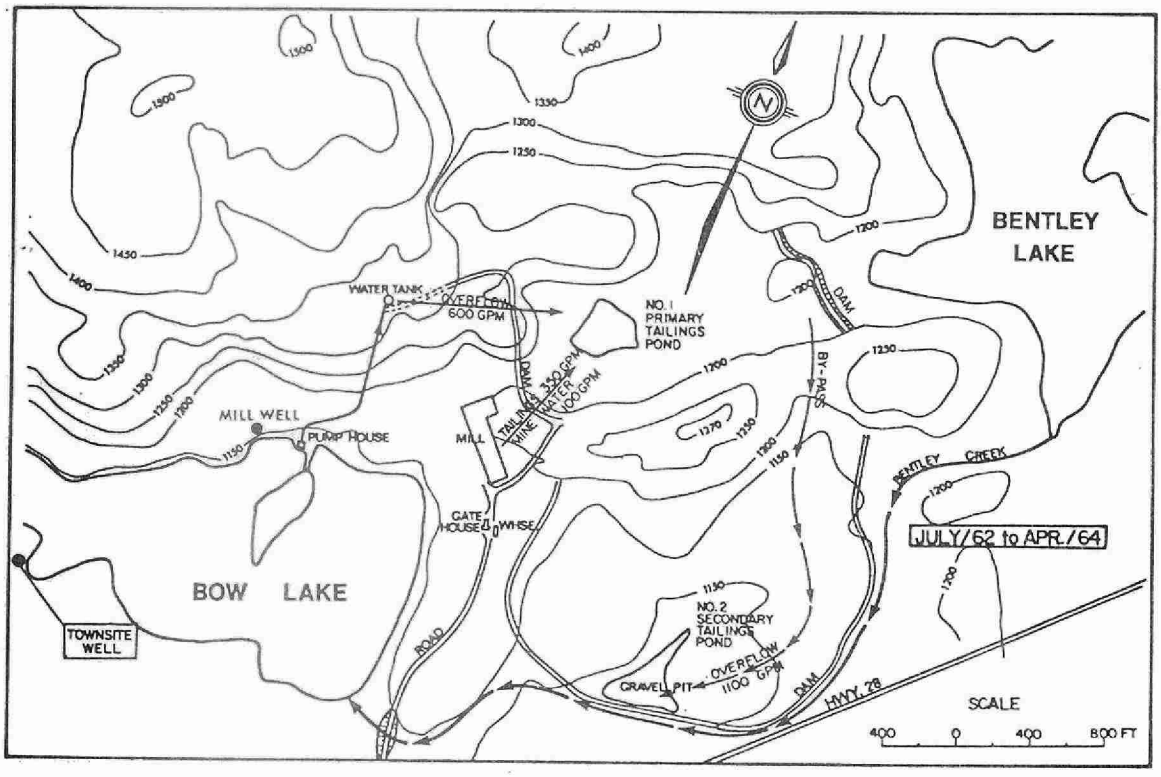


FIGURE 6

4. MINE OPERATIONS (cont'd)

4.2 Present Operation

The mill began operating again in September 1976 and the current system of handling of the tailings and waste water is shown on a simplified flow diagram on Figure 7. The overflow from the tailings pond flows by gravity to the mill. A portion of this is diverted to the mill circuit, presently at approximately 230 litres/min (50 IGPM). The balance is treated with barium chloride at a rate of 50 milligrams per litre then flows into a concrete settling pond with about three days retention capacity. The overflow at an average rate of 950 litres/min (210 IGPM) from the settling pond flows into a filter bed consisting of a pit in the natural sand and gravel overburden approximately 2.7 meters (9 feet) deep with a surface area of 2540 sq. meters (27,300 square feet). A section through the tailings pond is shown on Figure 8. Seepage from Tailings Pond No. 1 is controlled at the west end by a concrete cut-off wall.

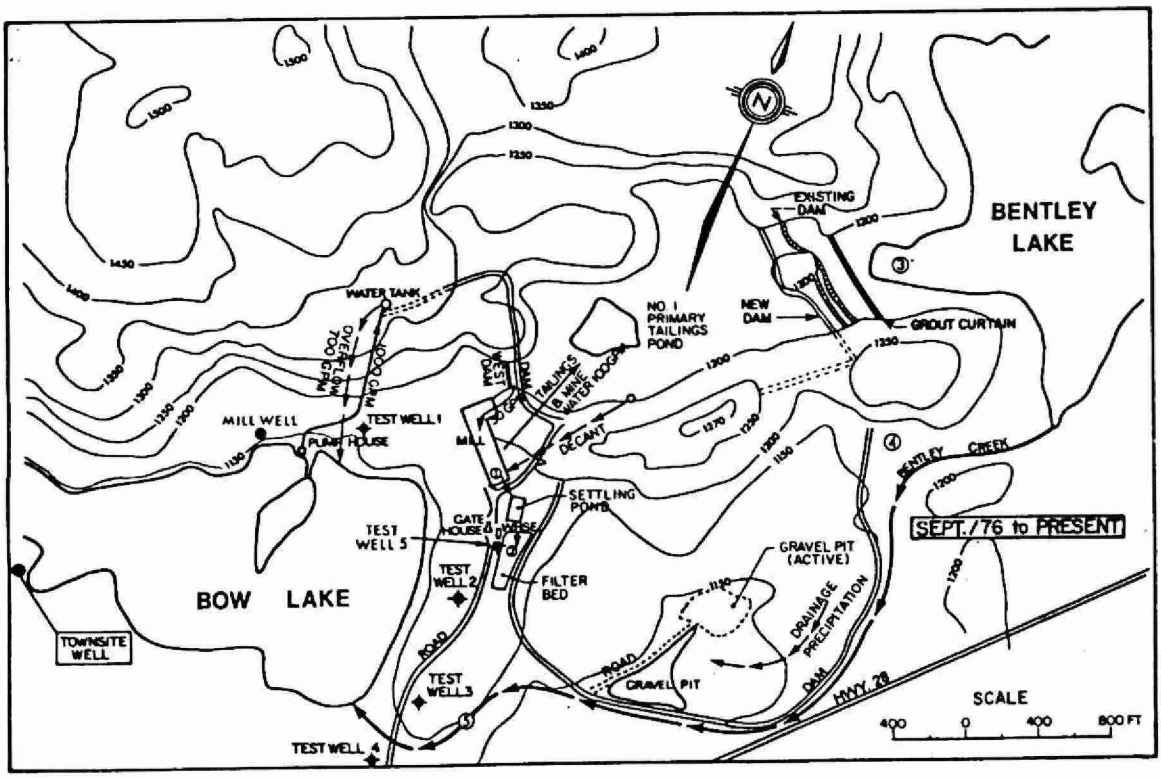


FIGURE 7

4. MINE OPERATIONS (cont'd)

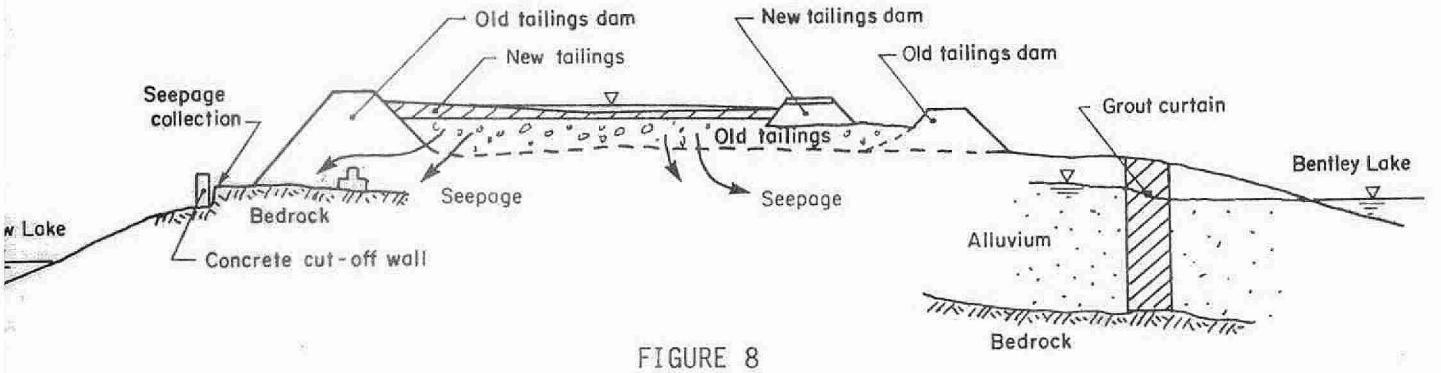


FIGURE 8

Seepage entrapped behind the wall is in the order of 136 to 227 litres per minute (30 to 50 IGPM) and is pumped into the mill for re-circulation. Seepage beneath the east end of Tailings Pond No. 1 takes place through the deep alluvial deposits towards Bentley Lake. The rate of seepage has been calculated to be in the order of 160 litres per minute (35 IGPM).

Although the bedrock was known to be shallower beneath the existing tailings dam at Bentley Lake, construction of a cut-off in this location would raise the groundwater levels beneath the toe of the new tailings dam and thereby reduce the stability. A suitable cross-section of dam to withstand the higher water levels would require much flatter slopes with an increase in cost of construction and a subsequent loss of storage capacity.

Essentially the construction process for the grout curtain consisted of installing slotted pipes through the alluvium down to and into the bedrock surface at a pre-determined spacing along three rows along the alignment of the curtain. A grout consisting of clay, water, cement, bentonite and occasionally calcium chloride was injected into the alluvium through the slotted pipes in the upstream and downstream row of holes. The layout of the slotted pipe locations and the subsurface profile determined from the installation are shown on Figures 9 and 10.

The centre line of holes were left untreated in order that access could be gained to the curtain at any future date to inject more grout or even a chemical grout if further cut-off of seepage is required. In addition, several test wells and a number of observation wells or piezometers were installed at the locations shown on Figure 9. These were used in pump draw-down tests conducted before and after construction of the curtain and are also used to obtain samples of the groundwater for analysis of dissolved Ra226. Several of the observation wells were constructed in sampling the grout curtain after completion.

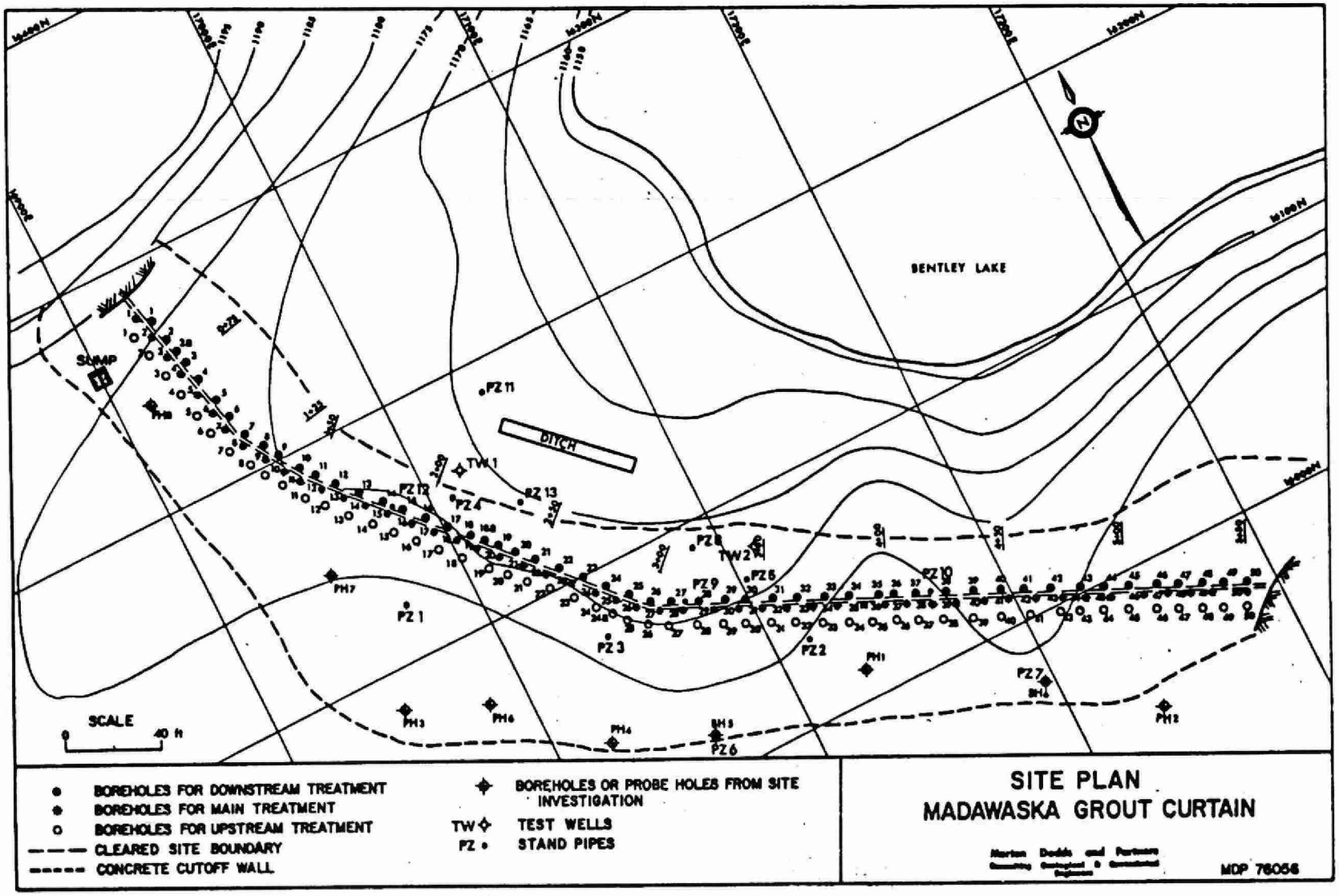

BENTLEY LAKE
SUMP
DITCH
PZ 11
PZ 12
PZ 13
PZ 4
PZ 8
PZ 9
PZ 10
PZ 1
PZ 3
PZ 2
PZ 7
PZ 6
TW 1
TW 2
PH 7
PH 1
PH 2
PH 3
PH 4
PH 5
PH 6
SCALE
0
40 ft
BOREHOLES FOR DOWNSTREAM TREATMENT
BOREHOLES FOR MAIN TREATMENT
BOREHOLES FOR UPSTREAM TREATMENT
CLEARED SITE BOUNDARY
CONCRETE CUTOFF WALL
BOREHOLES OR PROBE HOLES FROM SITE INVESTIGATION
TW TEST WELLS
PZ STAND PIPES
SITE PLAN
MADAWASKA GROUT CURTAIN
MDP 76056

FIGURE 9

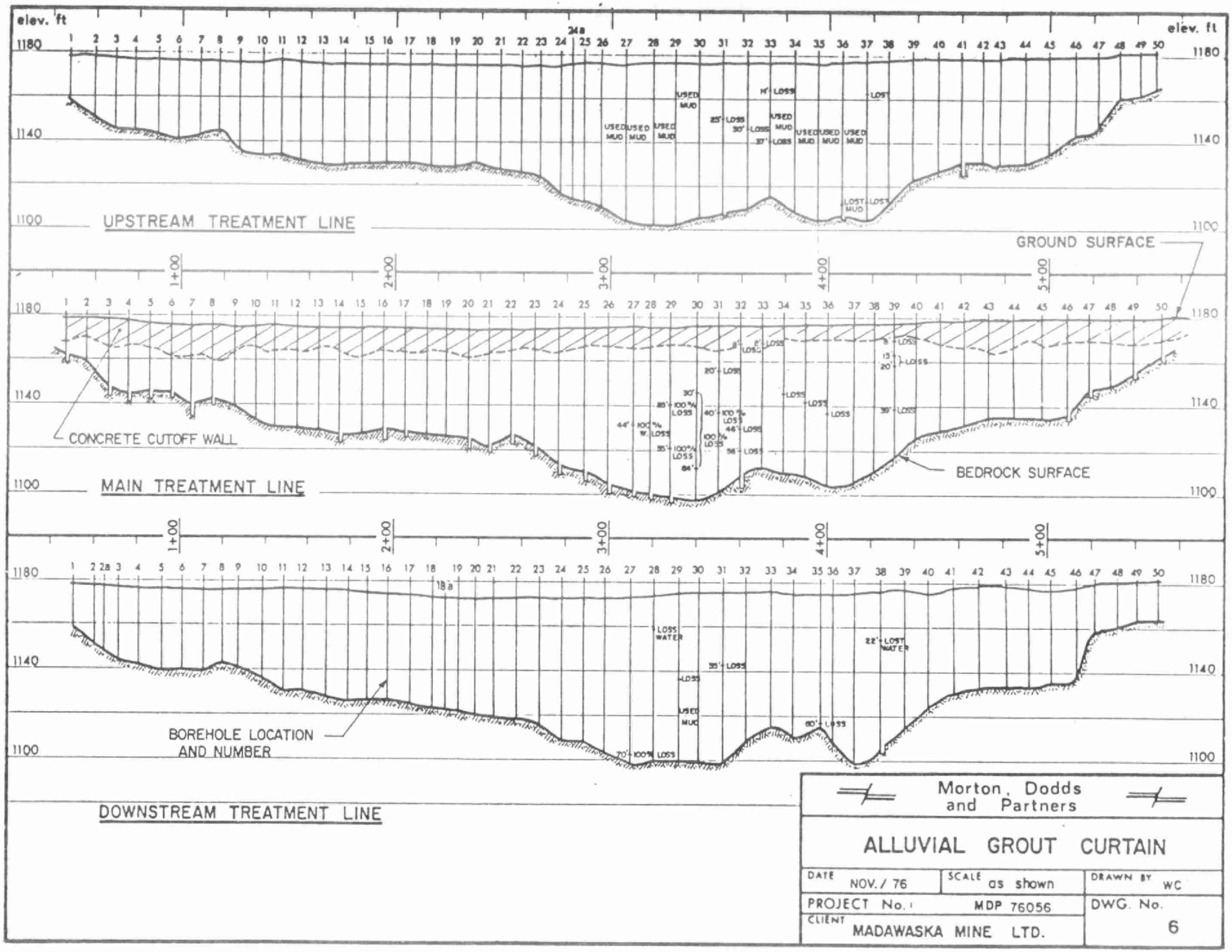

elev. ft
1180
1140
1100
UPSTREAM TREATMENT LINE
GROUND SURFACE
1+00
2+00
3+00
4+00
5+00
CONCRETE CUTOFF WALL
MAIN TREATMENT LINE
BEDROCK SURFACE
BOREHOLE LOCATION AND NUMBER
DOWNSTREAM TREATMENT LINE
Morton, Dodds and Partners
ALLUVIAL GROUT CURTAIN
DATE NOV./ 76
SCALE as shown
DRAWN BY WC
PROJECT No. MDP 76056
DWG. No. 6
CLIENT MADAWASKA MINE LTD.

FIGURE 10

4. MINE OPERATIONS (cont'd)

The pump draw-down test conducted after completion of the grout curtain show that the alluvium has been successfully grouted and that the major part of the seepage through the upper part of the alluvium has been retarded. However, the results show that a thin zone adjacent to the bedrock surface still allows seepage of groundwater.

5. RADIUM 226 CONCENTRATION

5.1 Closure Period

During the period of 1966 to 1976 when the mine was closed, samples of the water were taken by Ontario Environment officials and tested for levels of concentration of Ra226. The results of these tests are shown on Table I and are summarized on Table II. It is interesting to observe that levels of dissolved Ra226 in Bentley Creek near the gravel pit continued to reduce to a level of approximately 5 pCi/l despite the fact that from 1967 onward mine water was being pumped into this tailings area (Tailings Pond No. 2) at a rate of 410 litres/min (90 IGPM) with an estimated average dissolved Ra226 content of 35 pCi/l. This decline in Ra226 content is shown graphically on Figure 11.

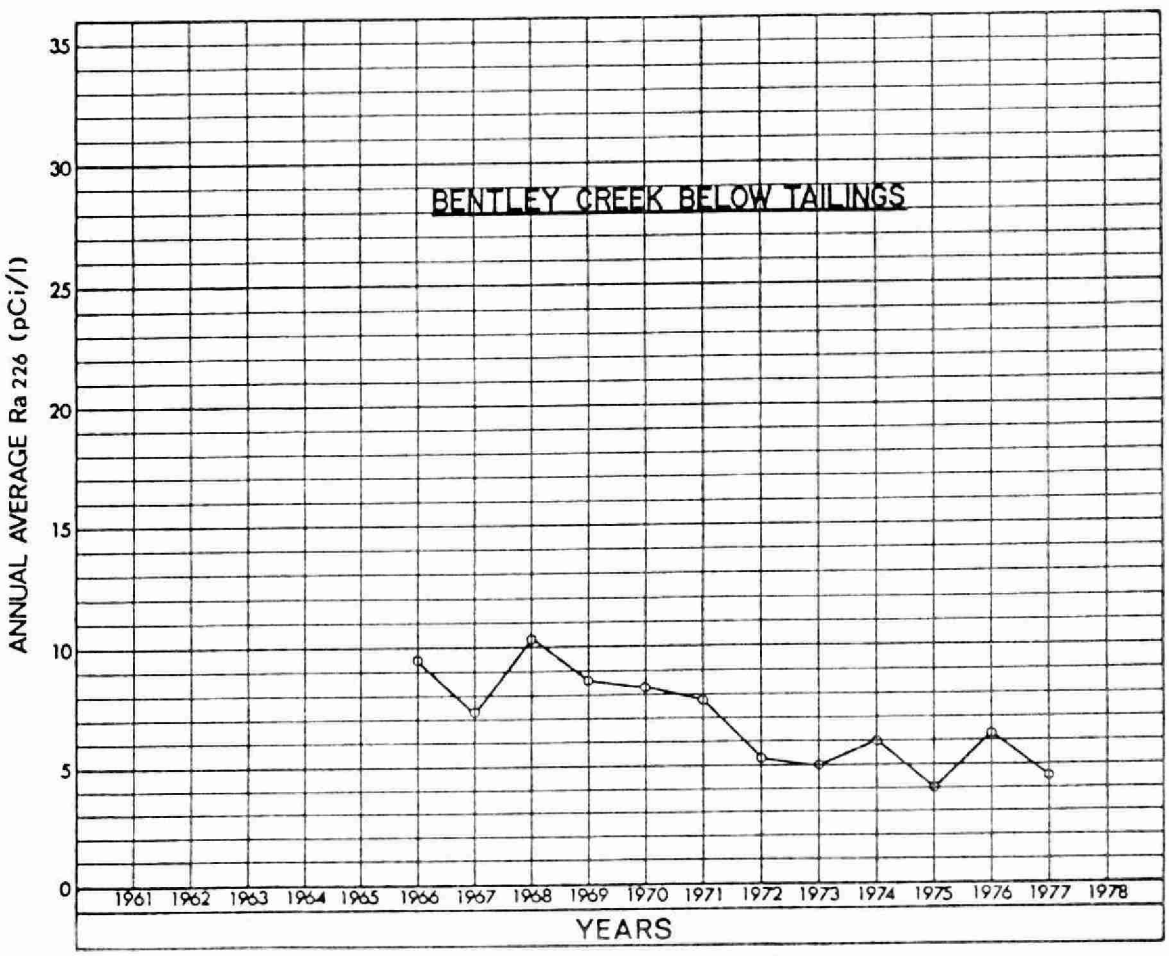


FIGURE 11

5. RADIUM 226 CONCENTRATION (cont'd)

Similar observations were recorded for Bow Lake where it crosses Highway 28. The results are shown on Table I and graphically on Figure 12.

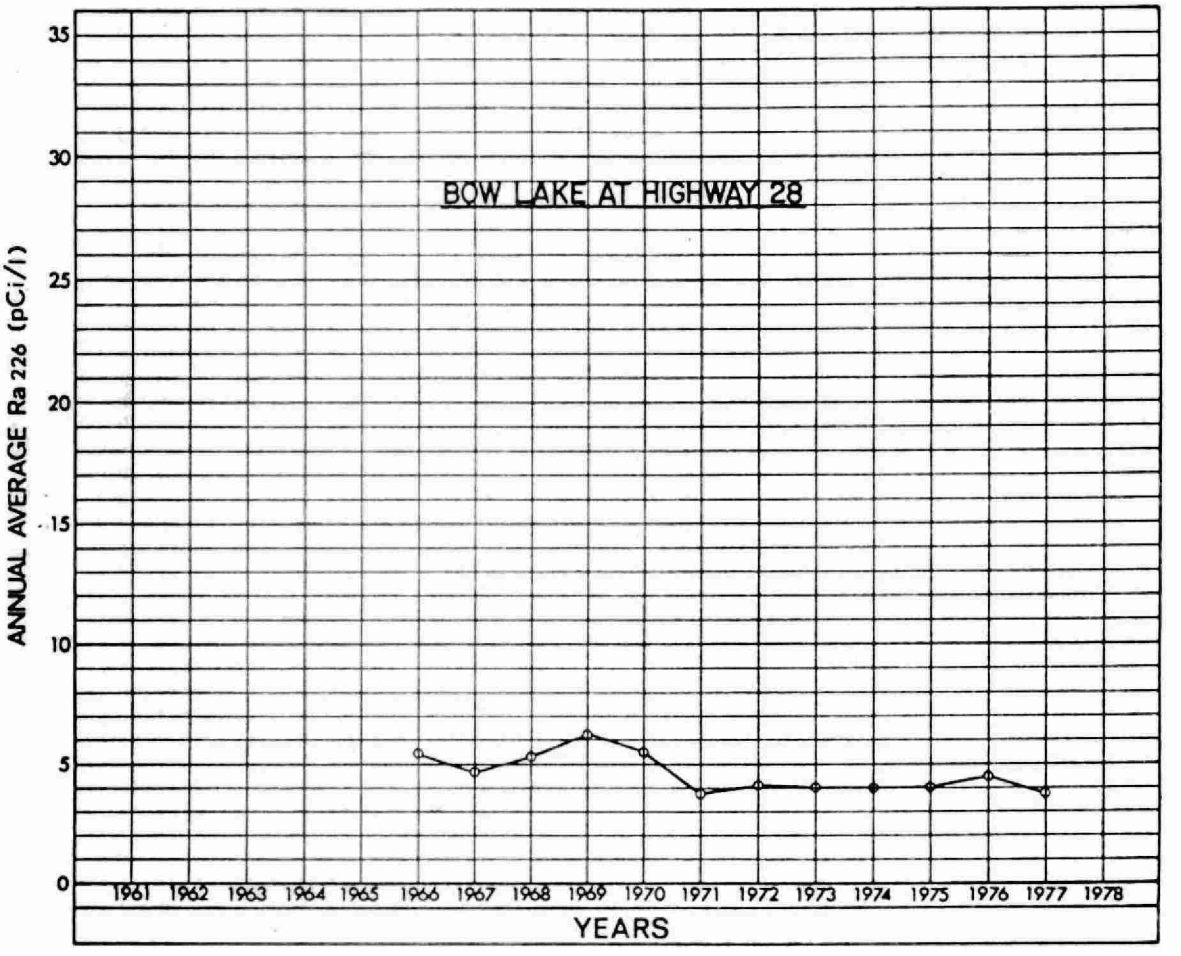


FIGURE 12

5. RADIUM 226 CONCENTRATION (cont'd)

Examination of the results of Ra226 measurements in Bentley Creek below the tailings after closure of the mine shows a possible link between the levels of dissolved Ra226 and the precipitation. For example in the year 1967, Table I shows levels of Ra226 in the months of August, September and October unusually high compared to the other months of the year. This same trend is evident in the preceeding year of 1966 and the following years of 1968 and 1969. The high levels follow the higher precipitation in the fall of each year. Examination of the precipitation records for the Bancroft area show unusually high levels of precipitation for the months preceeding as tabulated below:

YEAR	MONTH	Ra226 (pCi/l)	TOTAL PREC. (IN)	AVERAGE (IN)
1967	April	2.0 1.1	2.37	2.22
	May	3.0 2.5 3.5	2.96	2.85
	June		8.09	3.03
	July	3.5 4.0 3.5	4.77	3.15
	Aug.	7.0 17.0	3.17	2.84
	Sept.	28.0 26.0 28.0	4.78	3.12
	Oct.	11.0 11.0 5.0	6.18	2.70

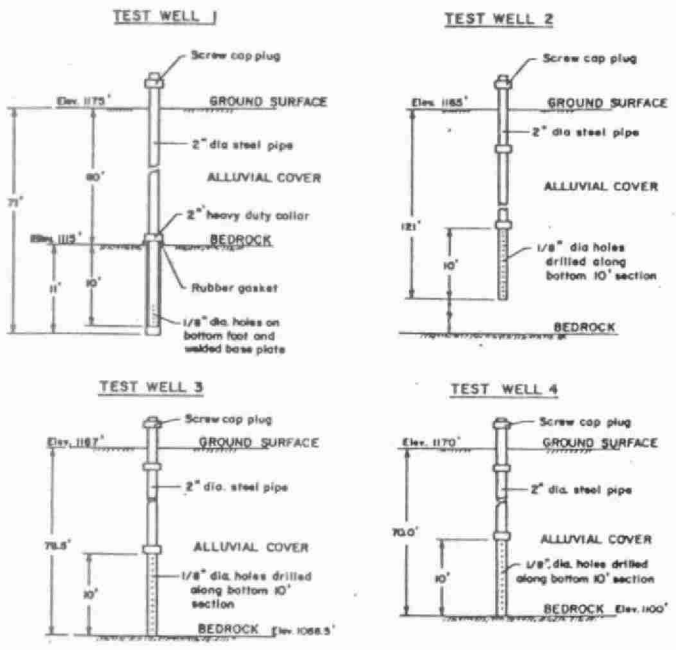
5.2 PRESENT OPERATION

The mine began operation again in September 1976 and the method of tailings disposal and waste water treatment are illustrated in Figure 7 and described in the text. The overflow from the concrete settling basin at an average rate of 950 litres/min (210 IGPM) contains dissolved Ra226 varying from 12 pCi/l in the winter to 2 pCi/l in the summer (see Table III).

5. RADIUM 226 CONCENTRATION (cont'd)

Test wells were constructed between the mill and nearby Bow Lake in order to allow sampling of the groundwater for analysis of dissolved Ra226. The locations of the wells are shown on Figure 7 and the details of the wells are shown in Figure 13. The results to date shown on Table IV indicate that very little or no dissolved Ra226 is entering the groundwater or that the natural sands and gravels are filtering out most of the dissolved Ra226 entering from the mining operation.

The seepage through the west end of the tailings pond at a rate of 136 to 227 litres/min (30 to 50 IGPM) is trapped by a concrete cut-off wall and returned to the mill circuit (see Figure 8). The content of dissolved Ra226 has been measured at 50 to 70 pCi/l. The tailings effluent entering the pond contains in the order of 2000 pCi/l of Ra226. Limited dilution and filtering action of the old tailings and sand and gravel in the tailings dam therefore reduces the dissolved Ra226 content by a factor of 30 to 40.



BOW LAKE TEST WELLS
NOT TO SCALE

FIGURE 13

5. RADIUM 226 CONCENTRATION (cont'd)

Calculations indicate that seepage takes place through the alluvium beneath the east tailings dam toward Bentley Lake at a rate of 160 litres/min (35 IGPM). This seepage consists of tailings effluent and precipitation infiltration through the new and old tailings and into the underlying natural sands and gravels. Although the grout curtain has not totally cut-off the seepage in this direction, it has apparently reduced the Ra226 content in the groundwater. The results of tests in water samples taken from observation wells upstream and downstream of the curtain and Bentley Lake are tabulated in Table V. The locations of the observation wells are shown on Figure 9. The measured levels of Ra226 in Bentley Lake over the period of time from May 1976 to the present are shown on Table I and graphically on Figure 14. In addition to monitoring the concentrations of dissolved Ra226 in the groundwater, samples of the clay grout were taken from upstream and downstream of the curtain and tested for total and dissolved Ra226. The results of these tests are shown on Table VI.

With respect to the grout curtain, test results to date allow the following observations:

1. Although the grout curtain does not cut-off all the groundwater seepage from Tailings Pond No. 1 to Bentley Lake, it appears to be instrumental in reducing the level of dissolved Ra226 content to acceptable levels.

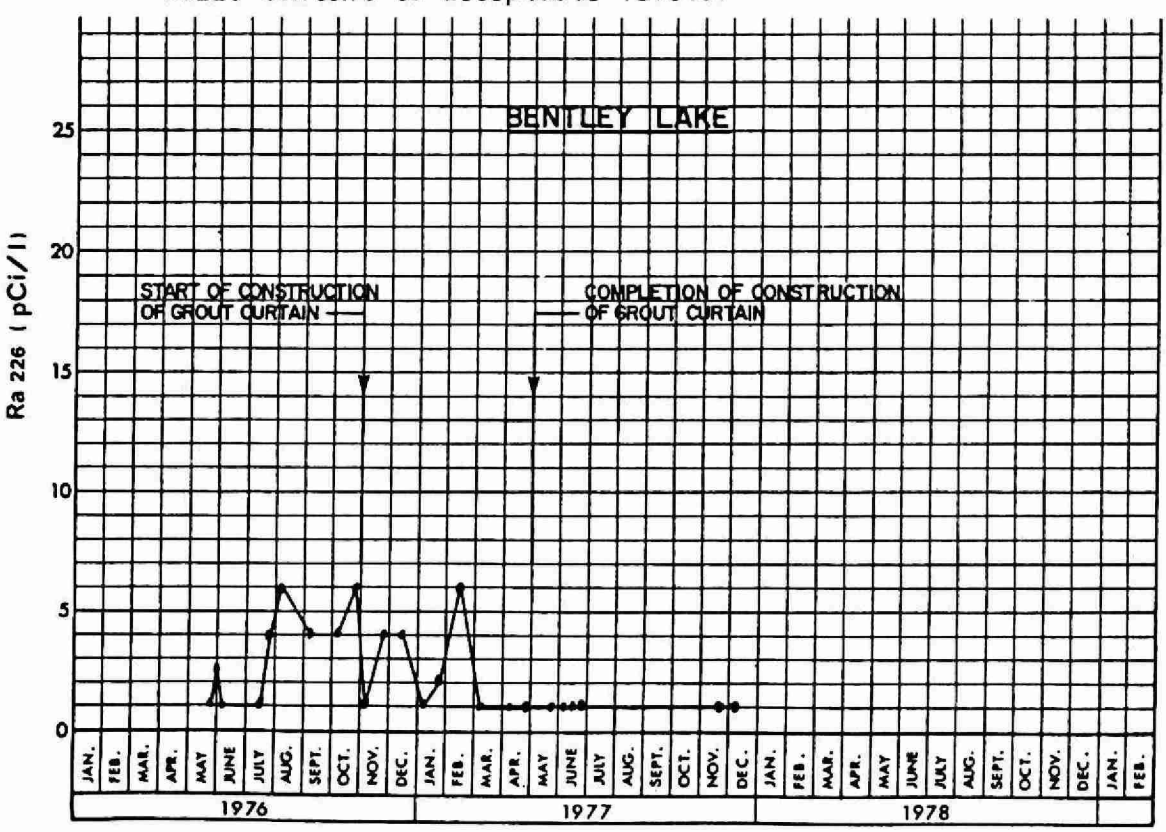


FIGURE 14

5. RADIUM 226 CONCENTRATION (cont'd)

2. The reduction in dissolved Ra226 content can likely be attributed to the following:

a) the grout curtain has increased the flow path thereby increasing the filtering action of the natural sands and gravels

b) the clay in the grout curtain reacts chemically with the Ra226, effectively bonding together. The test results on Table VI appears to confirm this, however a more detailed testing program would be necessary. Very little literature has been available regarding this process although it is known that Ra226 is geochemically similar to barium, and as such should be readily sorbed by clays and colloids.

SUMMARY

The current method of handling radioactive wastes by the Madawaska Mine has been extremely effective in reducing the amount of dissolved Ra226 to within current Federal guidelines. The levels of concentration of Ra226 in nearbly water bodies have continued to decline despite the re-activation of the mine. The levels around this active mine site can be compared to those measured by the Ontario Ministry of Environment near inactive mines in the same area on June 12, 1976.

Deere Creek, 16 miles west of Bancroft	7 pCi/l
Comrie Lake, 4 miles west of Cardif	14 pCi/l
Farrell Creek downstream of Dyno Tailings	15 pCi/l

The data available at this time would indicate the following factors contribute to this reduction in levels of dissolved Ra226 at the Madawaska Mine:

a) treatment of the tailings pond and overflow with Barium Chloride before emmission into the environment

b) filtering action of the natural sands and gravel in the area

c) chemical reaction of the clay grout with dissolved Ra226

ACKNOWLEDGEMENTS

The author is grateful to Madawaska Mines Limited for permission to publish this paper and for data and assistance provided in compiling the paper.

TABLE I

RADIUM 226 CONCENTRATION (pC1/1)

DATE					BENTLEY CREEK ABOVE TAILINGS	BENTLEY CREEK BELOW TAILINGS	BOW LAKE AT HWY. 28	REMARKS
YEAR	DAY	MONTH	DAY	MONTH				
1966			5	7		7.0		Composite samples by Ontario Water Resources Commission
	6	7	7	7			7.0	
			11	7		< 1	7.0	
	18	7	20	7		8.0	6.0	
	25	7	28	7		17.0	6.0	
			29	8		12.0	1.2	
	12	9	3	10		10.0	7.0	
				10		10.0		
			4	11		14.0	8.0	
	27	10	7	11		9.0	5.4	
				12			5.0	
			8	12		7.0	2.0	
1967	22	12	5	1		1.4	2.7	Composite Samples by Ontario Water Resources Commission
	18	1	7	2		2.0	2.9	
			7	2		1.5		
	22	2	6	3		6.0	3.5	
			6	3		2.3		
	21	3	4	4		2.0	4.0	
			7	4		1.1	2.8	
	10	4	8	5		3.0		
	18	4	11	5		2.5	4.0	
	16	5	31	5		3.5	5.0	
			31	5		6.0	5.0	
			29	6			4.3	
			7	7		3.5	5.0	
			14	7		4.0		
	17	7	28	7		3.5	6.0	
			4	8		7.0	4.5	
	9	8	23	8		17.0	4.0	
			8	9		28.0		
			11	9		26.0	6.0	
	7	9	21	9		28.0	6.0	
			3	10		11.0		
	3	10	24	10		11.0	6.0	
			26	10		5.0		
			7	11		4.0	8.5	
	2	11	22	11		3.7	3.0	
			5	12		5.0	6.0	
			6	12	1.2	4.5		

TABLE I (cont'd)

RADIUM 226 CONCENTRATION (pCi/l)

DATE					BENTLEY CREEK ABOVE TAILINGS	BENTLEY CREEK BELOW TAILINGS	BOW LAKE AT HWY. 28	REMARKS
YEAR	DAY	MONTH	DAY	MONTH				
1968			8	1		4.0	4.0	
	6	12	18	1	1.3	4.0	3.5	Composite samples by Ontario Water Resources Commission
	31	1	13	2	0.7	4.0	6.0	
			1	2		3.0	4.0	
	5	3				5.0	5.0	
	5	3	20	3		4.5		
			28	3	0.9		5.0	
	12	4	25	4	0.7	4.0	5.0	
	3	5				3.3		
			6	6	1.6			
	21	5	6	6		8	4.0	
	21	6	4	7	1.5	11	4.0	
	22	7	12	8	0.8	14	7.0	
	29	8	12	9	0.5	20	5.0	
	6	10	19	10	2.0	48	7.0	
	31	10	16	11	3.0	14	4	
	12	12	29	12	1.5	4	9.0	
1969	18	1	1	2	1.0	8	9.0	
	13	2	4	3	1.5	6	4.0	Composite samples by Ontario Water Resources Commission
	16	3	14	4	0.2	3.5		
	4	5	19	5	0.6	2.5	5.0	
	30	5	16	6	1.5	8.0	6.0	
	1	7	20	7	1.0	8.0	5.0	
			20	7			6.0	
			10	8		9.0	4.0	
			14	9		17.0	9.0	
			11	10		21.0	6.0	
			23	11		4.0	8.0	

TABLE I (cont'd)

RADIUM 226 CONCENTRATION (pCi/l)

DATE			BENTLEY CREEK ABOVE TAILINGS	BENTLEY CREEK BELOW TAILINGS	BOW LAKE AT HWY. 28	REMARKS
YEAR	DAY	MONTH				
1970	11	1		6.0	6	
	24	2		5	6	
	4	4		6	8	Samples by Ontario
	1	6		4	4	Water Resources
	14	7		17	4	Commission
	30	7		11	5	
1971	4	4	< 1	2	2	
	25	6	< 1	9	4	
	23	7	< 1	8	3	
	28	8	2	12	4	
	28	9	1	13	4	
	26	10	1	9	5	
	28	11	1	2	5	
1972	7	1		3	4	
	28	1	1	3	3	
	31	5		5	5	
	10	9	1	8	4	
	3	12	3	7	4	
1973	11	3	2	3	3	
	24	6		7	5	
	30	9	1	7	5	
	10	12	3	3	3	
1974	16	3	2	2	3	
	16	6	3	7	4	
	18	10	2	8	5	
1975			* 3.5	* 4.0	* 4.0	

* Average reported by M.O.E.

TABLE I (cont'd)

RADIUM 226 CONCENTRATION (pCi/l)

DATE			BENTLEY LAKE	BENTLEY LAKE ABOVE TAILINGS	BENTLEY LAKE BELOW TAILINGS	BOW LAKE AT HWY. 28	REMARKS
YEAR	DAY	MONTH					
1976	22	4	1	1	3	4	Sample by M.O.E.
	28	4	2.6	6	5.4	5.4	Sample by Madawaska Mine
	3	6	1	1	3	3	Sample by M.O.E.
	16	6		1	7	4	Sample by M.O.E.
	17	6		1	6	4	Sample by M.O.E. (verbal)
	19	7	< 1	1	6	4	Sample by M.O.E.
	29	7	4	1	8	10	Sample by M.O.E.
	19	8	6	3	9	4	Sample by M.O.E.
	7	9	4	4	8	3	Sample by M.O.E.
	7	10	4	3	8	3	Sample by M.O.E.
	28	10	6	4	6	4	Sample by M.O.E.
	9	11	1	1	3	2	Sample by M.O.E.
	23	11	4	7	12	8	Sample by M.O.E.
	17	12	4	1	4	*27	Sample by M.O.E.
1977	5	1	1	1	*22	3	Sample by M.O.E.
	25	1	2	3	5	6	Sample by M.O.E.
	25	1	2.9	3	2	4	Sample by M.O.E.
	15	2	7			7	Sample by M.O.E.
	15	2	6	3	2	4	Sample by M.O.E.
	8	3	< 1	1	3	4	Sample by M.O.E.
	7	4	2	3	6	1	Sample by Madawaska Mine
	7	4	1	1	3	3	Sample by M.O.E.
	29	4	< 1	< 1	6	2	Sample by M.O.E.
	26	5	< 1	3	2	2	Sample by M.O.E.
	6	6	< 1	2	5		Sample by Madawaska Mine
	13	6	< 1	< 1	4	2	Sample by M.O.E.
	29	6	1	< 1	7	5	Sample by M.O.E.
	29	11	1	2	3	5	Sample by Madawaska Mine
	13	12	1	3	12	5	Sample by Madawaska Mine
1978	2	2	7	1	1	3	Sample by M.O.E.

Note: 1. * Omitted as anamolous in averaging

2. Values less than 1 taken as 1 in averaging.

TABLE II

SUMMARY OF RADIUM 226 ANALYSES

YEAR:	1966		
LOCATION	N	$\bar{X}$	S
BENTLEY LAKE			
BENTLEY CREEK ABOVE TAILINGS			
BENTLEY CREEK BELOW TAILINGS	10	9.5	4.4
BOW LAKE AT HWY. 28	9	6.0	2.4

YEAR:	1967			1968			1969			1970			1971		
LOCATION	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S
BENTLEY LAKE															
BENTLEY CREEK ABOVE TAILINGS	1	1.2		11	1.3	0.7	6	<1	0.5				7	1	0.4
BENTLEY CREEK BELOW TAILINGS	26	7.3	8.1	15	10.3	9.4	10	8.7	6.5	6	8.2	5.0	7	7.8	4.3
BOW LAKE AT HWY. 28	19	4.7	1.5	14	5.2	1.6	10	6.2	1.9	6	5.5	1.5	7	3.8	1.1

YEAR:	1972			1973			1974			1975			1976		
LOCATION	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S
BENTLEY LAKE													12	3.2	1.9
BENTLEY CREEK ABOVE TAILINGS	3	1.7	0.7	3	2.0	1.0	3	2.3	0.6		* 3.5		14	2.5	2.1
BENTLEY CREEK BELOW TAILINGS	5	5.2	2.3	4	5.0	2.3	3	6.0	3.2		* 4.0		14	6.3	2.6
BOW LAKE AT HWY. 28	5	4.0	0.7	4	4.0	1.2	3	4.0	1.0		* 4.0		13	4.5	2.2

YEAR:	1977			1978		
LOCATION	N	$\bar{X}$	S	N	$\bar{X}$	S
BENTLEY LAKE	15	2.0	1.9			
BENTLEY CREEK ABOVE TAILINGS	14	2.0	1.0			
BENTLEY CREEK BELOW TAILINGS	13	4.6	2.8			
BOW LAKE AT HWY. 28	14	3.8	1.7			

NOTE: N = number of readings
$\bar{X}$ = arithmetic mean
S = standard deviation
* = average reported by M.O.E.

TABLE III

RADIUM 226 CONCENTRATION IN MINE OPERATIONS (pCi/l)

DATE		MINE WATER	TAILINGS POND NO. 1 SURFACE WATER	TAILINGS POND OUTFALL	TAILINGS DAM DECANT OUTFALL	TAILINGS POND INFLUENT TO BaCl TREATMENT TANK	BARREN SOLUTION BEFORE NEUTRALIZATION	BaCl TREATMENT TANK DISCHARGE	SETTLING POND OUTFALL	GRAVEL FILTER BED	SURFACE WATER TAILINGS POND NO. 2	SEEPAGE THROUGH WEST TAILINGS DAM	REMARKS
YEAR	MONTH & DAY												
1961	May			1662									Faraday Mine Laboratory
	Aug	180		620									Composite samples by mine, tested by Ontario Department of Health
	Sept 13 - Oct 11	147		1025									
	Oct 11 - Nov 15	127		2270									
	Dec	149		2015									
1962	Jan 12 - Mar 1	247		2340									
	Mar 1 - Apr 4	144		1360									
	Apr 4 - May 2	214		1660									
	May	283		2280									
	June	194		960									
	July	359		1100									
	Aug 15 - Sept 13	170		1500									
	Sept 14 - Oct 16	348		1140									
	Oct 16 - Nov 13	256		1035									
	Nov 15 - Dec 12	400		1480									
1963	Dec - Jan	365		1660									
	Feb - Mar 7	362		833									
	Mar 7 - Apr 10	270		880									
	Apr 11 - May 14	291		700									
	May 15 - June 26	290		690									
	June 27 - Aug 21	350		722									
	Sept	311		657									
*	Oct	395		853									* omitted as anomolous in averaging
	Nov	299		212									
	Dec	330		3860									
1964	Jan	288		1990									
	Feb	540		1700									
	Mar	498		5310									

CURRENT OPERATIONS

YEAR		DAY	MONTH										
1976		22	4	46	33								Sampling and testing by Ministry of Environment
		19	8	83									
		7	9			520							
		18	11			3200							
		23	11			3200							
		17	12			2000	4200			20	12	9	
1977		5	1			1850		1210		3	6		
		25	1			1900		1180		14	5		
		8	3			2114		2245	367		3		
		7	4			4700		2000	140		6		
		28	4			2800		2800				70	
		29	4			2900		2300			3	74	50
		26	5					3100			2		
		13	6			1860			120				
		29	6			350		1200	14		2		
		29	11			7330							
		13	12				4840						51
1978		2	2			2700		3770			17		68

TABLE IV

RADIUM 226 CONCENTRATION IN WELLS (pCi/l)

DATE			TOWNSITE WELL	MILL WELL-BOW LAKE	STEPHENSON'S WELL - SAND POINT @ 32' DEPTH	RON JONAS SAND POINT @ 40'. First 20' DUG & TILED	SARGISON WELL 8" CASING TO 40-45 FT.	STEWART WELL - DUG TO 30 FT.	BOREHOLE 1	BOREHOLE 2	BOREHOLE 3	TINNEY WELL - 18' LOT 19 Conc. 10, FARADAY TWP.	TEST WELL NO. 1	TEST WELL NO. 2	TEST WELL NO. 3	TEST WELL NO. 4	TEST WELL NO. 5	BENTLEY LAKE ESTATES HOUSE	PITTS DUG WELL 20 FT.	BOW LAKE LODGE
YEAR	DAY	MONTH																		
1961	5	5	<1																	
1962	15	8	<1																	
1962	14	9	<1																	
1962	16	10	12																	
1963		11	2																	
		2	<1																	
		3	<1																	
		4	<1																	
		5	1																	
		6	1																	
		9	<1																	
		10	<1																	
		11	1																	
		12	<1																	
1964		1	<1																	
		2	1																	
		3	<1																	
1976	22	4	1	1	1															
	17	6			1	1	1													
	19	7						2												
	19	8	1	<1					196	120	23									
	28	10		3																
	9	11					3													
	23	11										2								
1977	5	1											1			12				
	25	1											1							
	7	4											<1	1	1	2				
	13	6											<1	1	<1	1		1		
	29	6																		<1, <1
	13	12											3	2	6	4	1			
1978	2	2											<1	1						

NOTE: Borehole 1, 2 and 3 were located in Tailings Pond No. 1 near north-east dam at Bentley Lake

TABLE V

CONCENTRATION OF RADIUM 226 (DISSOLVED)
UPSTREAM AND DOWNSTREAM
OF GROUT CURTAIN (pCi/1)

DATE SAMPLED	Upstream					Downstream					REMARKS
	PZ3	PZ7	Sump			PZ4	PZ5	TW1	TW2		
May 26,1977	3	4				2	1				MOE Report RPL 77-371 9/8/77
June 29,1977	8	2				3	< 1				MOE Report RPL 77-493 21/9/77
Aug. 8,1977	3	3				3	2				Madawaska Mine
Sept. 1,1977	-	-						1	1		Madawaska Mine
Sept. 19,1977	5	14				1	2				Madawaska Mine
Oct. 24,1977	29	38				5	1				" "
Nov. 29,1977	40	38	2					1	7		" "
Dec. 13,1977	6	7	13					< 1	2		" "

TABLE VI

TOTAL RADIUM 226 IN SOIL SAMPLES

B.H. #	SAMPLE #	DEPTH (ft)	DATE OF SAMPLING	DATE OF TEST	TOTAL Ra-226 (picog/g)	REMARKS
PZ2	4	25.0-26.5	14/7/77	28/10/77	7 ± 6	±6 - Standard Deviation
PZ2	5	30.0-31.5	14/7/77	28/10/77	8 ± 6	±6 - Standard Deviation
PZ9	14	40.0-41.5	26/7/77	28/10/77	5 ± 4	±4 - Standard Deviation
PZ9	23	64.5-66.0	27/7/77	28/10/77	6 ± 4	±4 - Standard Deviation

NOTES: 1. Tests were performed by Atomic Energy of Canada Limited

2. For each test, a sample weight of about 15 to 20 gm was sealed in a plastic capsule and stored for approximately 30 days to allow sample to reach an equilibrium state, then sample was subject to testing by a mass spectrometer.

3. According to A.E.C.L., the Radium-226 in these samples is about the lowest level the A.E.C.L. has tested. This accounts for the relatively large standard deviations in the measurements.

SESSION IV

Chairman: Dr. J. D. Norman,
President, Pollutech Ltd.,
Oakville, Ontario

Unique Features of Wastewater Treatment Facilities at Polysar's Styrene II Production Unit
T. A. Constantine,
Chief Environmental Engineer,
M. M. Dillon Ltd.,
Consulting Engineers and Planners,
London, Ontario

G. E. Thompson

Hydrogeological Control and Clean-up of Soil and Groundwater Contaminants at Northern Wood Preservers, Ltd.
G. E. Thompson, Manager,
Process Engineering and
Environmental Group,

Dr. H. Husain, Process Engineer,
and J. Parry, Chief Hydrogeologist,
W. L. Wardrop and Associates Ltd.,
Engineering Consultants,
Winnipeg, Manitoba, and
P. J. Gilbride,
Abitibi-Price Northern Wood
Preservers Ltd.,
Thunder Bay, Ontario

Pretreatment of Vegetable Waste at H. J. Heinz Company, Leamington
D. Smit, Manager,
Quality Assurance Department,
Leamington, Ontario
T. E. Eyre,
Chief Environmental Engineer,
J. D. Lee Engineering Ltd.,
Brantford, Ontario

Treatment and Recovery of Emulsified Oil by Ultrafiltration
Dr. G. K. Dhawan,
Research and Development
Supervisor, Reverse Osmosis,
Electrohome Limited,
Kitchener, Ontario

Unique Features of Wastewater Treatment Facilities at Polysar's Styrene II Production Unit

by
T.A. Constantine, Chief Environmental Engineer, M.M. Dillon Ltd., Consulting Engineers and Planners, London, Ontario

The Polysar Corporation commissioned the construction of a world class **styrene** production facility for their Sarnia, Ontario, petrochemicals and synthetic rubber complex. The main design-build contractor was the Badger Corporation of Cambridge, Mass., and M.M. Dillon Ltd. of London, Ontario, were the waste treatment consultants.

The paper presented at the Conference dealt mainly with two unique aspects of the waste treatment facilities at Polysar's new plant:

- the use of ozonation for the destruction of phenolic compounds; and
- the use of precoat vacuum filtration for dewatering aluminum hydroxide sludges.

Unfortunately, the paper as written could not be reproduced in these proceedings as there was concern that proprietary information on the production process could be derived from a careful study and interpolation of the data on the performance of the waste treatment facilities.

A general paper on ozonation from which a good deal of the talk and slides at the Conference was extracted can be obtained by contacting the author.

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Hydrogeological Control and Clean-up of Soil and Groundwater Contaminants at Northern Wood Preservers, Ltd.

by

G.E. Thompson,
W.L. Wardrop and Associates Ltd.

A. Introduction

This paper deals with a specific problem of creosote contamination in Lake Superior adjacent to the Northern Wood Preservers Ltd. plant in Thunder Bay. Although the particular problem is interesting in itself, the principles used in its solution are much more significant. At the plant, wood products are treated with creosote, chromated copper arsenate and pentachlorophenol in an autoclave under heat and pressure. As part of the day to day operation, small amounts of preservative, mainly creosote, reach the ground adjacent to the plant. Some of these spilled materials have been washed directly into the Lake by surface runoff. But the major portion have infiltrated into the landfill underlying the site and then moved laterally into the Lake. The resulting high phenol content in the water and the accumulation of creosote on the bottom have seriously degraded the lake environment adjacent to the plant.

In order to rectify the situation, Northern Wood have had dredging undertaken to remove the accumulated creosote from the Lake bottom and have commissioned W. L. Wardrop & Associates Ltd. to conduct investigations aimed at preventing continued movement of creosote through the landfill into the Lake. The results of these investigations are the topic of this discussion.

For the creosote in the landfill, the objective was first to develop a method to prevent continued migration to the Lake, and second to dispose of any contaminated effluent that might be generated. An investigation of the site led us to recommend the installation of well points to prevent the movement of creosote to the Lake. Pilot studies conducted on the effluent from the well system concluded that the most appropriate treatment for the effluent are ozonation and activated carbon. The two main themes of the paper then are:

1. The use of hydrogeological principles to devise a mthod to control contaminant movement in the subsurface.
2. The use of pilot studies to identify a best solution to deal with contaminated effluents.

B. Hydrogeological Control

a) Groundwater Flow Principles

In the past, the spillage of toxic materials on the ground was normally not considered cause for serious concern. The ground absorbed the material, it disappeared, and that appeared to be the end of it. However, in an increasing number of cases, these substances are coming back to haunt us. A farmer's well two kilometers from the spill site goes sour, a nearby lake or stream becomes contaminated or a major groundwater supply for a city becomes degraded. The apparent complexity of movement of contaminants underground would appear to defy effective control and clean-up measures. However, hydrogeologists have gradually developed principles to define the movement of groundwater, and are now in a position to provide effective methods of control and clean-up for a wide variety of situations.

A brief outline of some basic principles of groundwater flow will serve as a background. Groundwater is part of a continually moving cycle wherein rainwater percolates downward to the water table, moves laterally

and reappears in a lake or stream (Figure 1). This is a highly simplified version of the groundwater portion of the hydrologic cycle. Groundwater movement in the near surface materials is controlled by the configuration of the water table wherein groundwater flows in the direction of the water table slope. In deeper zones, the direction of groundwater flow is determined by the hydraulic head in that the groundwater moves from points of high hydraulic head to points of low hydraulic head. Here we are interested primarily in the near surface zone and will restrict ourselves to the water table situation.

Figure 2 depicts the movement of a contaminant from a spill site to a lake by means of the groundwater flow system. In order to control the movement of shallow groundwater, and thus control the movement of a contaminant, one need only manipulate the water table slope. This can be accomplished by pumping water out of the ground or pumping water into the ground. For example, in the case of Figure 3, a pumping well is used to intercept the contaminant and actually remove it. Figure 4 depicts a well into which water is injected, raising the water table in the surrounding formation and causing the contaminant to move in the opposite direction.

b) Contaminant Movement at Northern Wood

For the creosote contamination problem at Northern Wood Preservers, the use of pumping-out wells is considered to be the most desirable solution to prevent movement of creosote to the Lake. The landfill projects out into Lake Superior, and the wood preserving plant is located immediately adjacent to the Lake, as shown on Figure 5. The spillage of creosote takes place as the treated wood is moved along narrow gauge tracks from the autoclaves to a loading area. Drippings from the wood infiltrate into the ground, join the groundwater flow system and thence migrate to the Lake (Figure 6). The plant has been in operation for 40 years and a heavy concentration of creosote covering an area of 20,000 square metres has accumulated in the landfill.

c) Hydraulic Characteristics of Landfill

Fifteen observation wells were completed in the landfill to gain an appreciation of the characteristics of the landfill materials, the water table configuration and the extent of the contamination. A test well was installed in the zone of highest contamination and a 24-hour pumping test conducted to obtain information on the hydraulic parameters of the landfill. Slug tests were performed on selected observation wells.

The landfill consists primarily of fine sands which extend to a depth of 3 - 5 metres and are underlain by a very low permeability clay. The water table in the fine sands is within one metre of surface, and the water table gradient is 0.004 to 0.002 adjacent to the Lake. The gradient is affected to a large extent by fluctuations in Lake level. The permeability of the landfill materials as indicated by the pumping test and slug tests varies considerably, but the average is estimated to be 10 metres/day at a flow gradient of 1. Based on the permeability of the sand and the gradient of the water table, the rate of migration of the creosote-water mixture to the Lake is estimated to range from 2 - 10 cm/day. This may seem slow but the distance from the spillage point to the lake is less than 12 metres so that within three months the creosote could reach the Lake.

d) Analysis of Contaminant Levels

Water samples from the observation wells were analyzed for phenols, copper and chromium. Phenols were determined by chloroform extraction from samples, sodium hydroxide extraction of the chloroform extract, dilution, acidification, distillation, and colorimetric determination of the phenols in the distillate. Copper and chromium were determined by atomic adsorption. The amount of creosote in soil samples collected during the test drilling was determined by extraction using petroleum ether.

Concentrations of up to 60 milligrams/litre phenols were measured in the groundwater in the most highly affected zone. At some points, soil samples contained in excess of one percent of creosote. Low copper and chromium levels were encountered suggesting that spillage of chromated copper arsenate is not a major concern. The groundwater did exhibit significant levels of pentachlorophenol (PCP) which is highly toxic to aquatic life.

e) Well Point Control System at Northern Wood

In view of the low permeability of the landfill materials, the use of well points pumping at low rates is a practical solution to prevent the migration of creosote to the Lake. The drawdown of the water table will create an effective hydraulic barrier. It was recommended that a series of wells be installed along the length of the contaminated zone as shown in Figure 7. The results from the test well installation suggest that a yield of 0.15 litres per second (2 IGPM) from each well will be sufficient to effectively prevent the migration of creosote to the Lake. Initially the system will have to be pumped full time in order to clean-up the accumulated creosote and recovery of significant quantities of creosote is anticipated. However, at a later stage it is anticipated that periodic pumping will be sufficient to provide effective control in view of the relatively slow migration rates. Monitoring wells will be installed as part of the system to check contaminant levels immediately adjacent to the Lake and allow manipulation of the pumping regime to obtain satisfactory results at the least operating cost.

C. Treatment of Well Point Effluent

The installation of the well system will prevent further contamination of the Lake, but it will be necessary to provide treatment for the groundwater removed from these wells. At a pumping rate of approximately 0.15 litres per sec. (2 IGPM) from each well, a volume in excess of 100,000 litres per day (22,000 IGPD) would be generated. The quality of this groundwater after sedimentation is presented in Table 1. It is apparent that treatment of the groundwater extracted from the wells is required before this water could be discharged to a municipal sewer system or a surface waterbody.

a) Alternative Treatment Processes Considered

Northern Wood Preservers presently operates a biological oxidation plant for the treatment of aqueous liquid wastes from the preserving operation. The plant performs satisfactorily on wastewater containing phenols up to 800 mg/l and reduces the level of phenols in the effluent to approximately 1 mg/l. This is the only biological oxidation plant operating on wood preserver waste in Canada. Unfortunately, this plant is operating at or near its capacity and would be unable to accept the additional load created by the groundwater extraction wells. The flow rate from the wells would be approximately four times the present flow rate to the biological oxidation plant.

However, it was apparent that the use of biological oxidation was a logical first process for consideration for treatment of the well point effluent. A review of the technical literature with respect to treatment of phenolic effluents indicated that the use of activated carbon and chemical oxidation should also be considered.

Because the effluent from our test well exhibited a high degree of variability and showed evidence that significant quantities of creosote oils might be recovered and returned to the process, it was decided that whatever process was finally selected it would have to be proceeded by an oil-solid-water separation step such as a gravity clarifier or an API separator.

In order to evaluate the three processes under consideration and to provide design data for a full scale plant, bench scale pilot plants of each of the processes under consideration (biological oxidation, activated carbon treatment and chemical oxidation) were set up in the laboratory of W. L. Wardrop & Associates Ltd. in Winnipeg. The effluent from the test well installed as part of the groundwater investigation was pumped into drums and shipped to the laboratory. This effluent was used in all tests.

b) Biological Oxidation Pilot Tests

A schematic diagram of the biological oxidation pilot plant is shown in Figure 8, along with data on the performance of the plant when operating under stable conditions. It should be noted that the BOD in the feed indicated on Figure 8 is the result of adding additional carbonaceous material. This was necessary because when only phosphorus and nitrogen were added and phenols were the only carbon present, the plant exhibited the symptoms of a biological system operating under starved conditions. It was concluded that if the effluent from the well point system were mixed with the feed to the existing biological plant and fed to a new biological plant sized accordingly, results indicated on Figure 8 could be achieved with little difficulty. It is important to note, however, that the very toxic component, pentachlorophenol, was reduced very little in the biological oxidation process, and still posed a significant environmental hazard.

On the basis of some relatively long-term tests extending over a period of approximately four months, it was concluded that very little could be done with the biological oxidation process to improve its performance in PCP removal. As a result, despite the success in phenol removal, it was decided that biological oxidation is not a viable process for treating the well point effluent at Northern Wood.

c) Activated Carbon Pilot Tests

A 180 cm by 2.5 cm activated carbon column is shown in Figure 9 was also used to treat settled well point effluent. Several runs of varying length and feed rate were carried out over an extended period of time. The results shown on Figure 9 are representative of most of the runs made. It is significant that the carbon capacity did not vary significantly even if the loading rates were varied. It is apparent from the results of the pilot tests that activated carbon is a technically feasible and obviously very desirable treatment process with respect to removal of COD, phenol and PCP. However, a total of approximately 1/3 of a cu. metre (12 cu. ft.) of activated carbon would be required to treat each day's production from the well point system. If the carbon were to be removed from the company's property, a safe landfill disposal or incineration facility would have to be provided. Alternatively, a carbon regeneration system could be installed.

d) Chemical Oxidation

Our Firm has been engaged in applied research and development of ozone technology for several years. Because of this involvement and a knowledge developed in treating low levels of phenol in potable water supplies, it was decided that the use of ozone would be a logical system for evaluating the chemical oxidation alternative. Our Firm's ozonation pilot plant was set up to evaluate the performance of ozone treatment on the well point effluent. A schematic of the pilot plant arrangement is shown in Figure 10. As the results on Figure 10 show, performance of ozone in the removal of phenols and pentachlorophenol from the well point effluent is very good. After a total ozone dose of 387 mg/l, phenols were reduced from 60 mg/l to 3.5 mg/l and PCP was reduced from 2.05 mg/l to 0.15 mg/l. Although no extended runs using this system have been made to date, it is apparent that chemical oxidation remains a viable alternative for treatment of the effluent from the well point system.

e) Economic Evaluation of Alternative Treatment System

At this time we are carrying out a detailed economic evaluation of two possible treatment alternatives. The first alternative shown in Figure 11 consists of an API separator, ozonation system and gravity sand filter. The preliminary tests using this system indicate that a high quality, non-toxic effluent will be produced. The second alternative being investigated is a combination of an API separator and a battery of activated carbon columns as shown in Figure 12. Again this process will produce a high quality, non-toxic effluent.

Both systems will initially recover a significant quantity of creosote for recycle to the wood preserving process. The main advantage of the ozonation system is that no auxilliary treatment process is required because the problem organics, namely phenol and pentachlorophenol, are destroyed within the system.

It is anticipated that we will complete our economic evaluation within the next few weeks and a report will be presented to Northern Wood Preservers outlining recommended treatment process to be combined with the well point groundwater control system.

D. Concluding Remarks

We hope that this paper has illustrated the benefits that can be obtained from the application of basic hydrogeological principles to provide practical solutions to environmental problems related to the movement of contaminants in the subsurface. The example cited deals specifically with a wood preserving plant but the same procedures are applicable to a wide range of chemical substances which have infiltrated into the subsurface and migrated laterally within the groundwater flow regime. Although manipulation of the groundwater system can control and remove the contaminant, the effluent often must be treated before final disposal. As previously outlined, the selection of the most suitable treatment method must be based on a sound technical and economic evaluation. The use of pilot testing plants is a reliable, practical method of comparing alternative treatment techniques to achieve the desired final effluent characteristics.

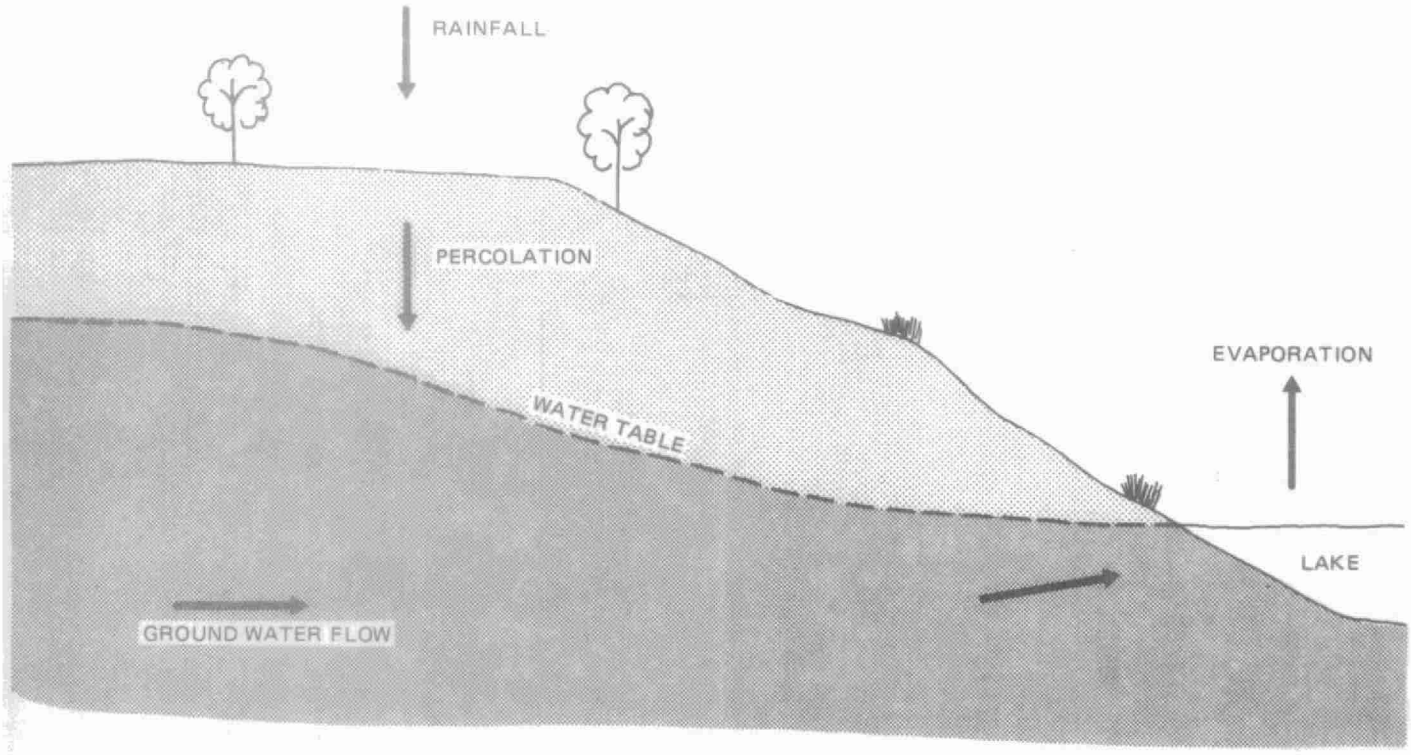
TABLE I

Quality of Groundwater

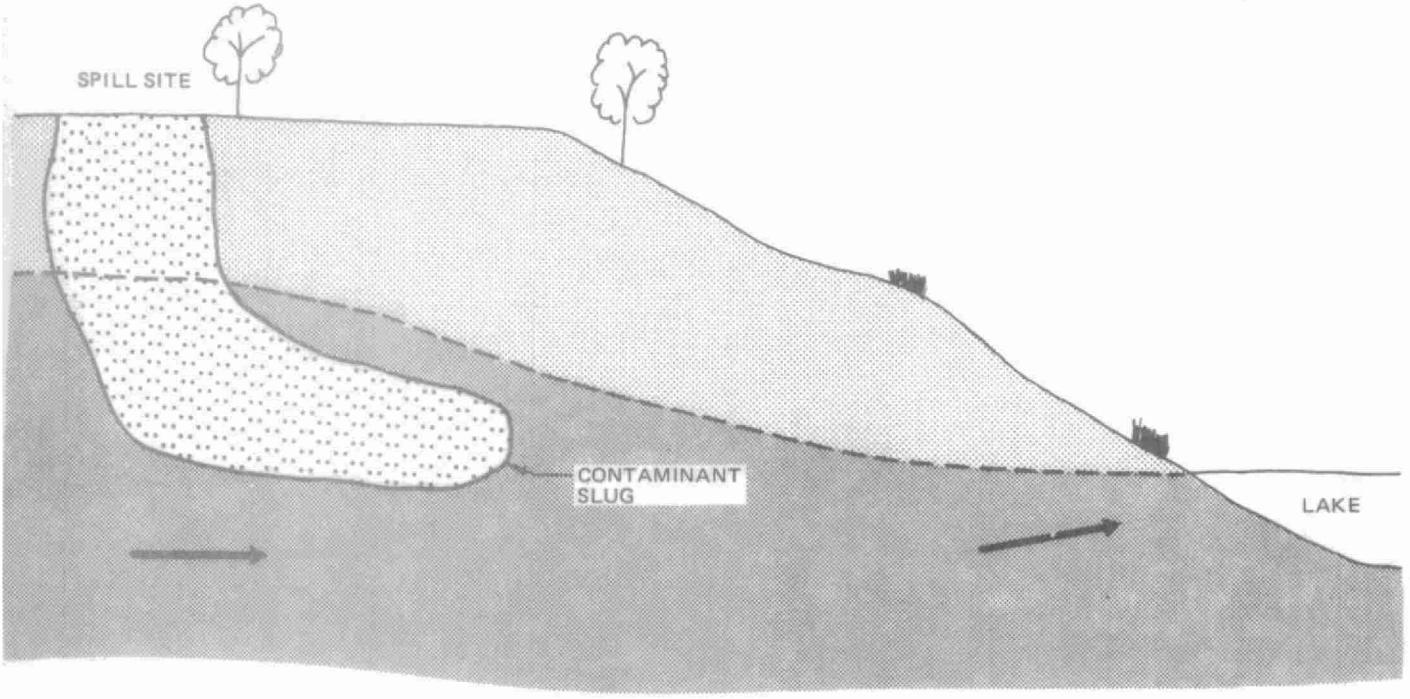
Extracted by Well Point System

Following Sedimentation

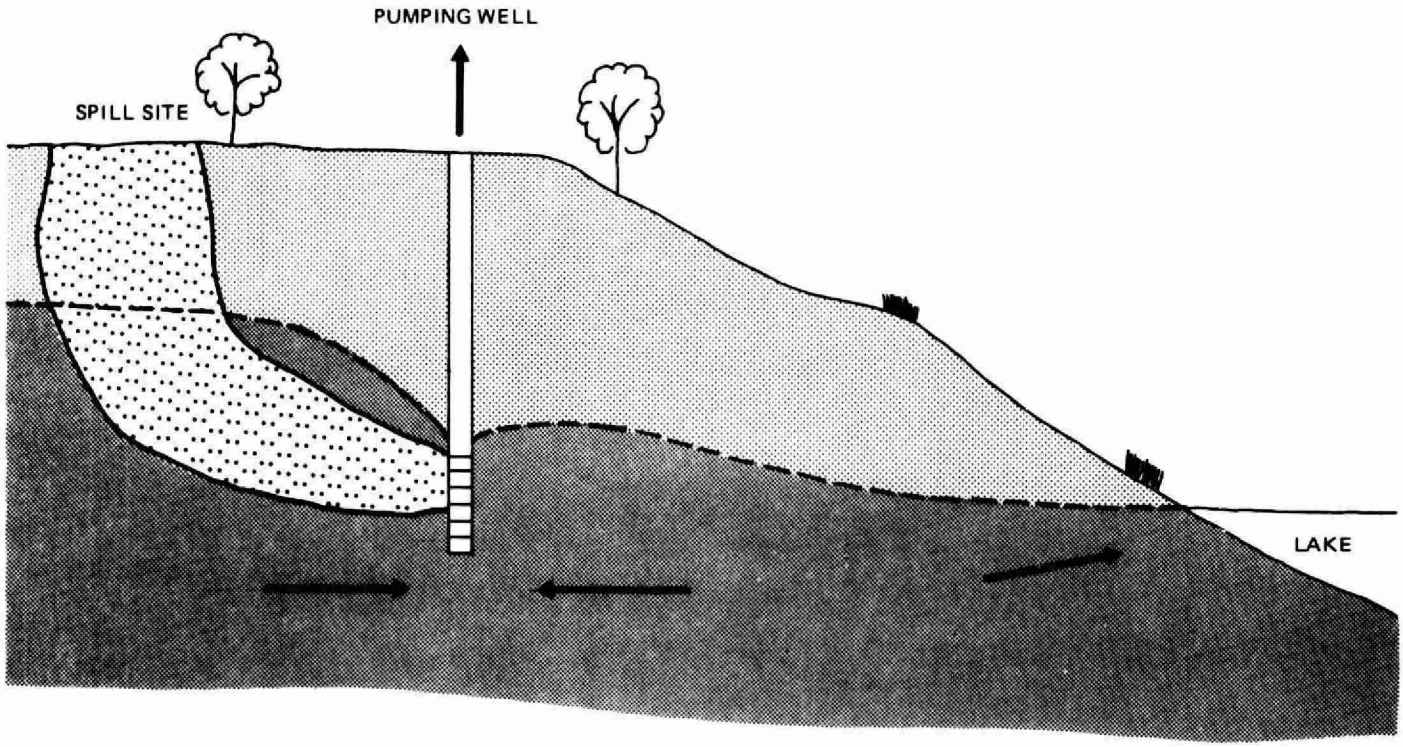
BOD	50	-	190	mg/l
COD	300	-	600	mg/l
Phenol	25	-	60	mg/l
PCP	2.05	-	3.35	mg/l
S.S.	100	-	500	mg/l
Oil	5	-	120	mg/l



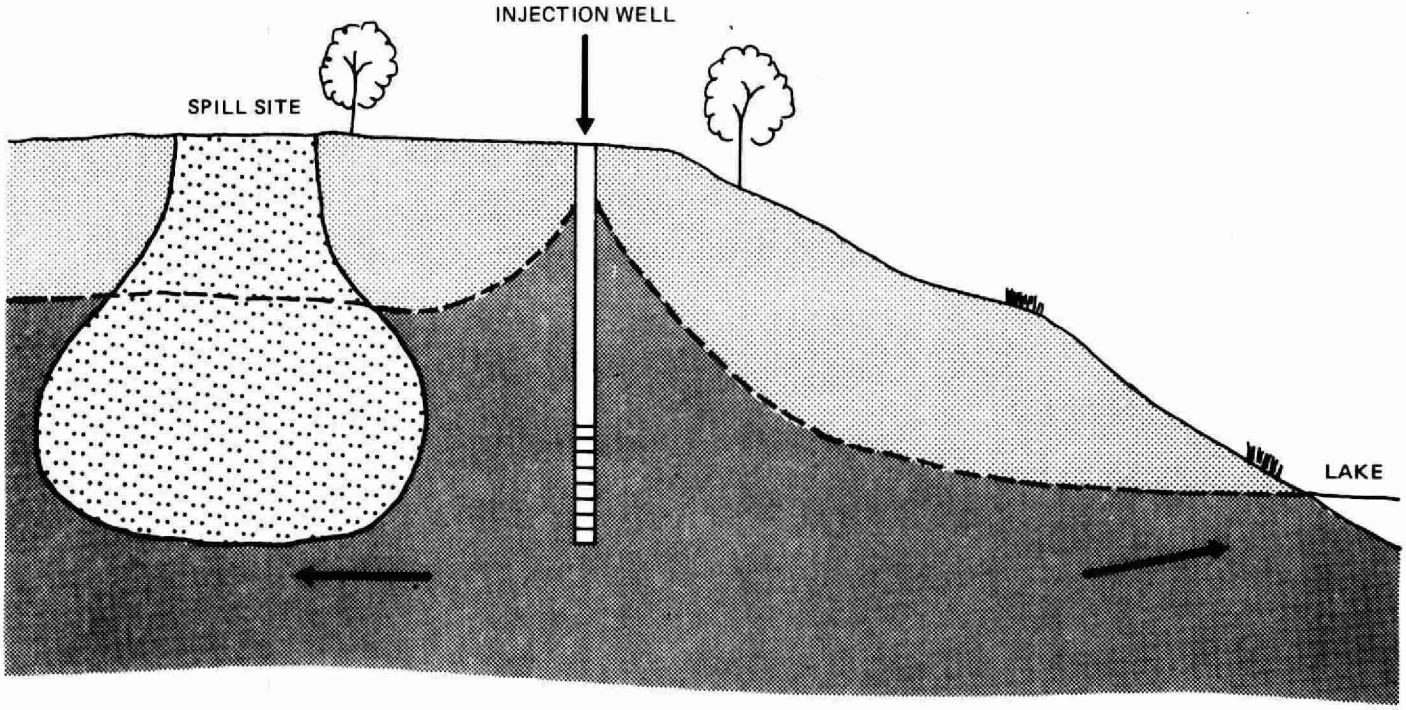
GENERAL GROUND WATER SYSTEM FIG. 1



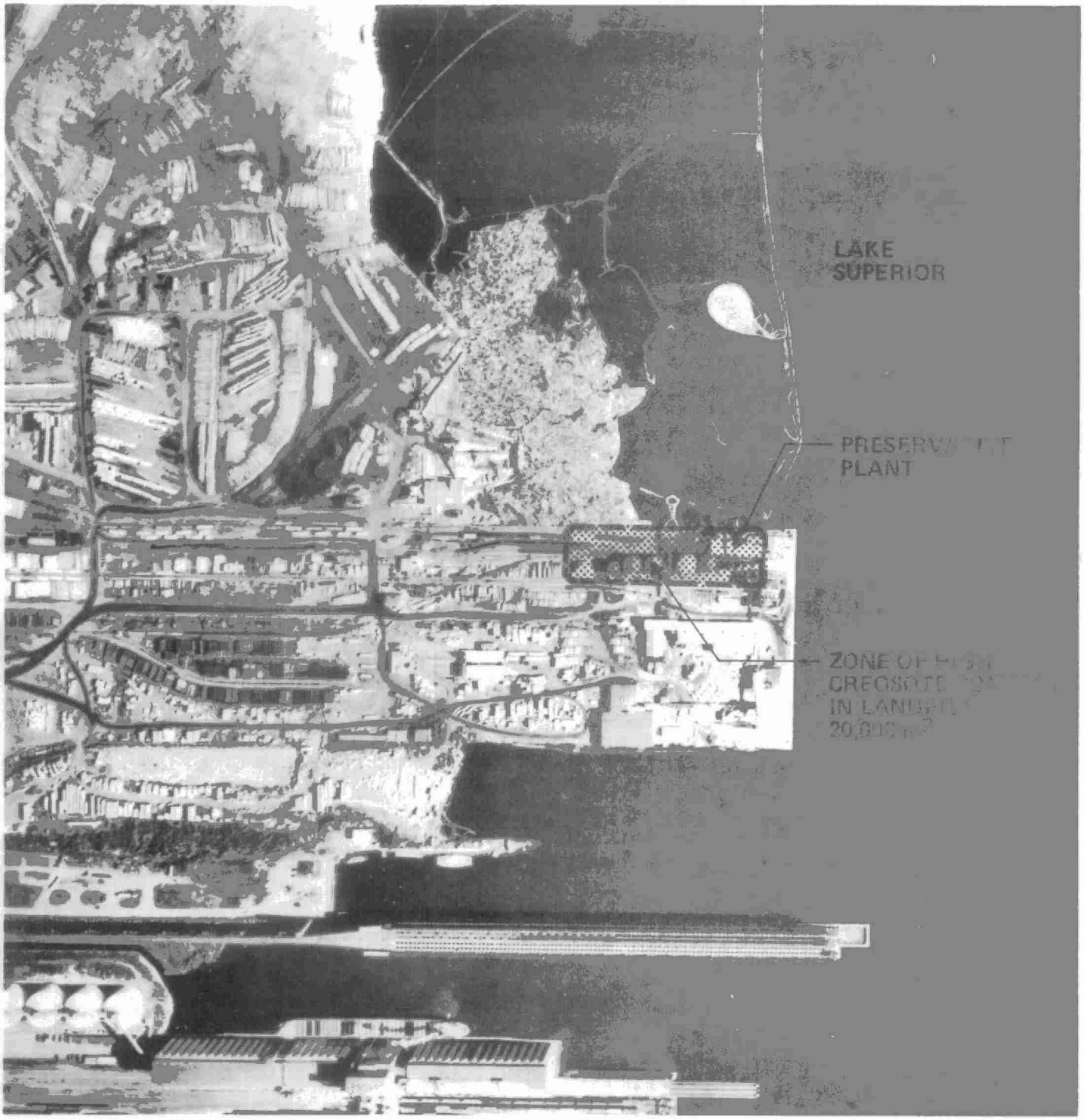
CONTAMINANT MOVING IN GROUND WATER FLOW SYSTEM FIG. 2



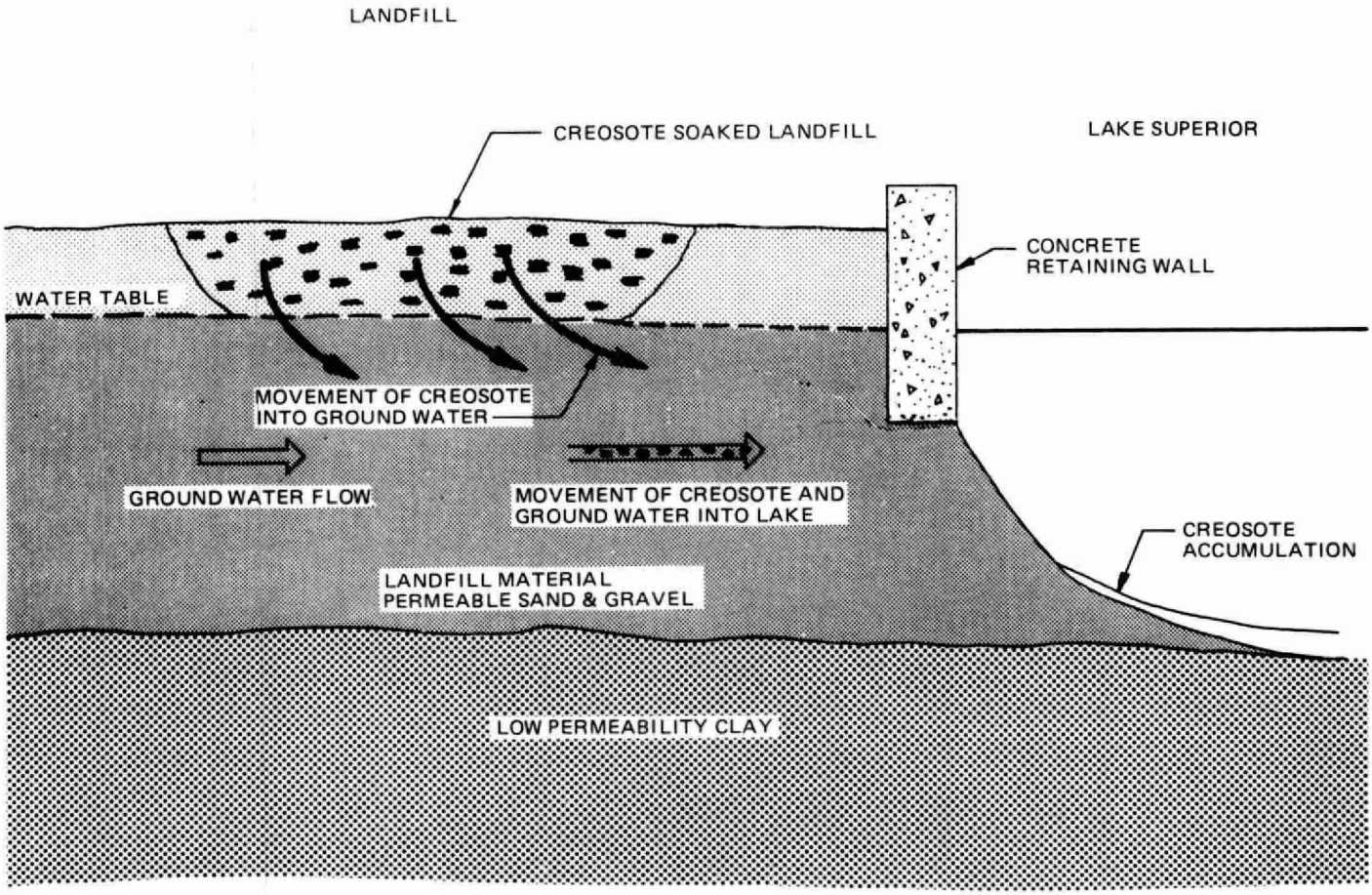
CONTROL AND CLEAN-UP OF CONTAMINANT USING PUMPING WELL FIG. 3



CONTROL OF CONTAMINANT USING INJECTION WELL FIG. 4

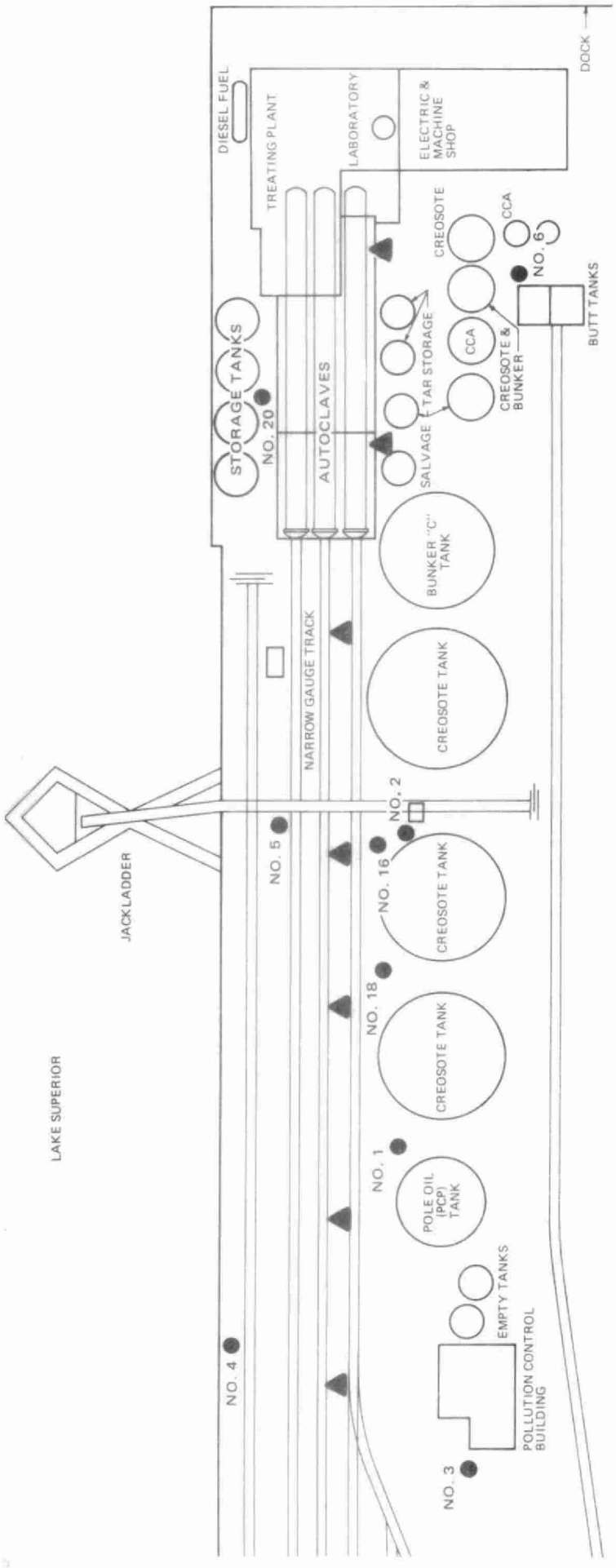


AERIAL VIEW OF NORTHERN WOOD PRESERVERS SITE FIG. 5



SCHEMATIC CROSS-SECTION THROUGH NORTHERN WOOD PRESERVERS SITE SHOWING MOVEMENT OF CREOSOTE TO LAKE SUPERIOR

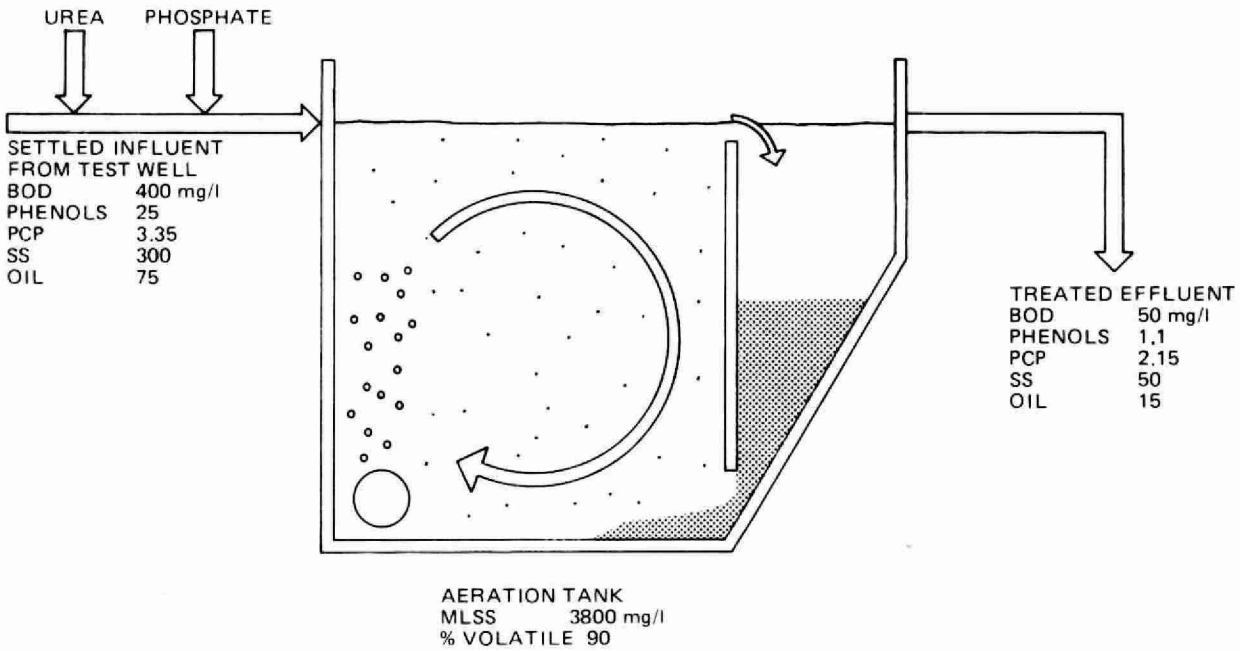
FIG. 6



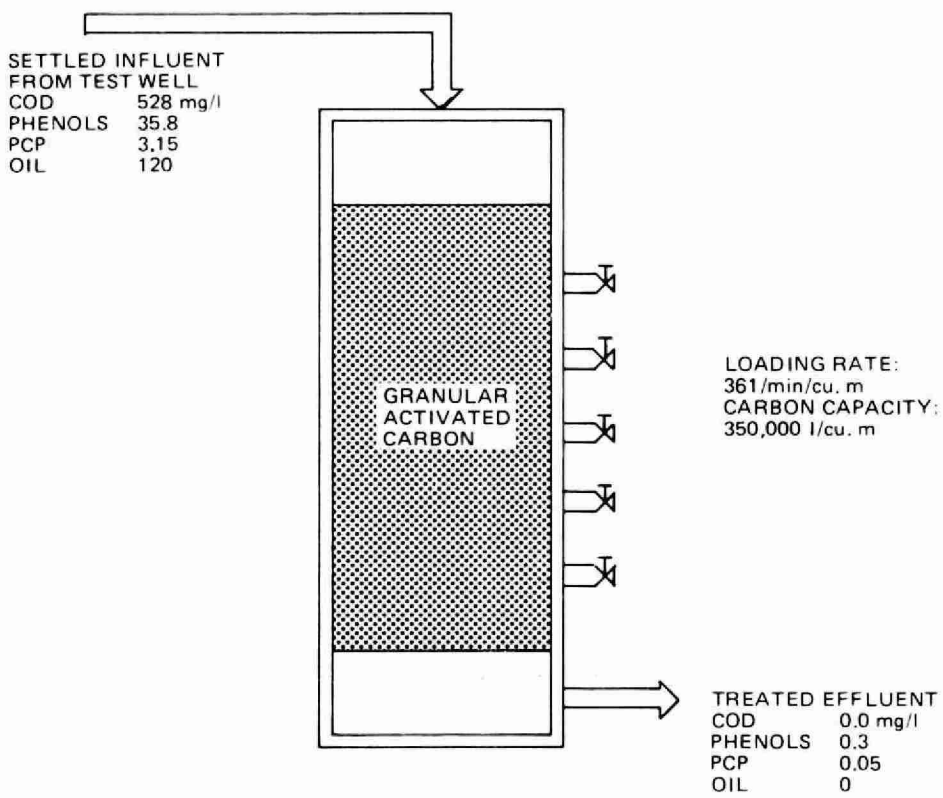
▲ LOCATION OF PROPOSED WELL POINT

● LOCATION OF SAMPLING WELLS

LOCATION OF PROPOSED WELLS FIG. 7



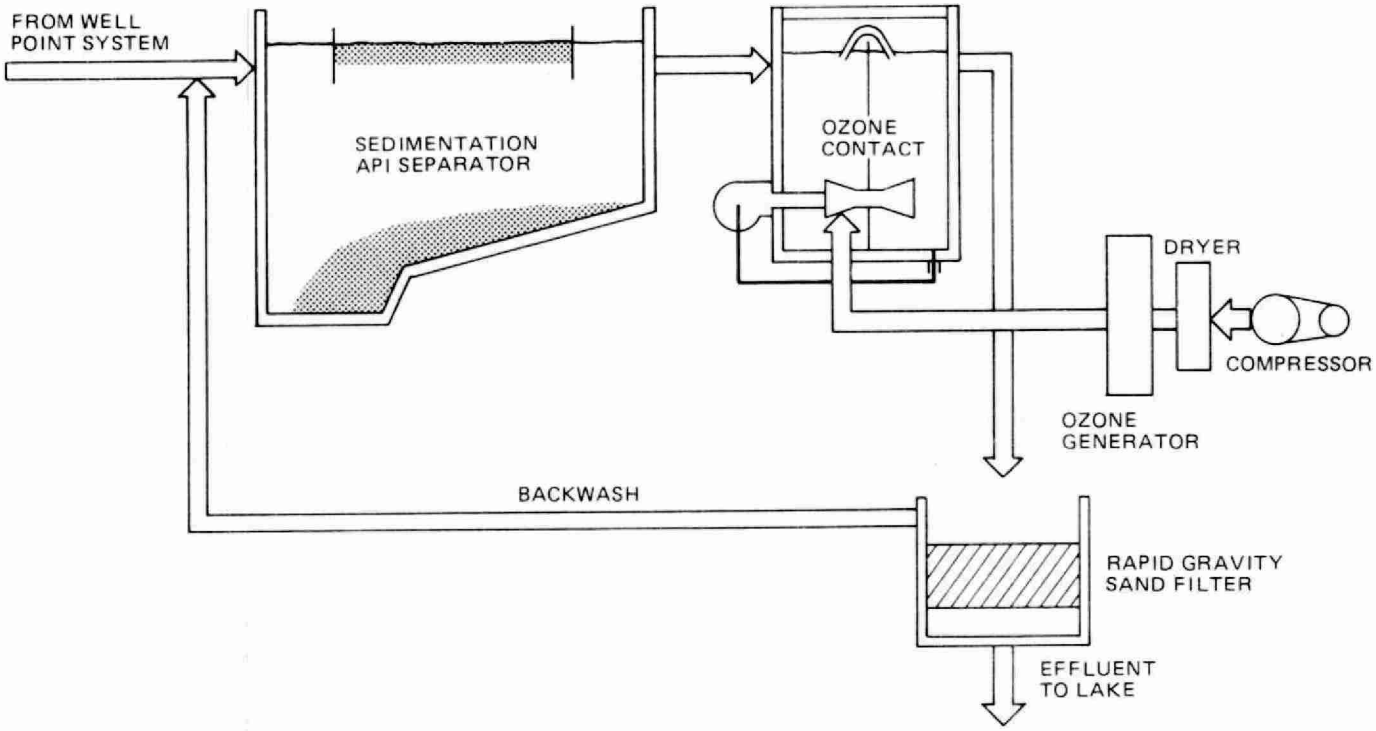
BIOLOGICAL OXIDATION **FIG. 8**



ACTIVATED CARBON TREATMENT **FIG. 9**

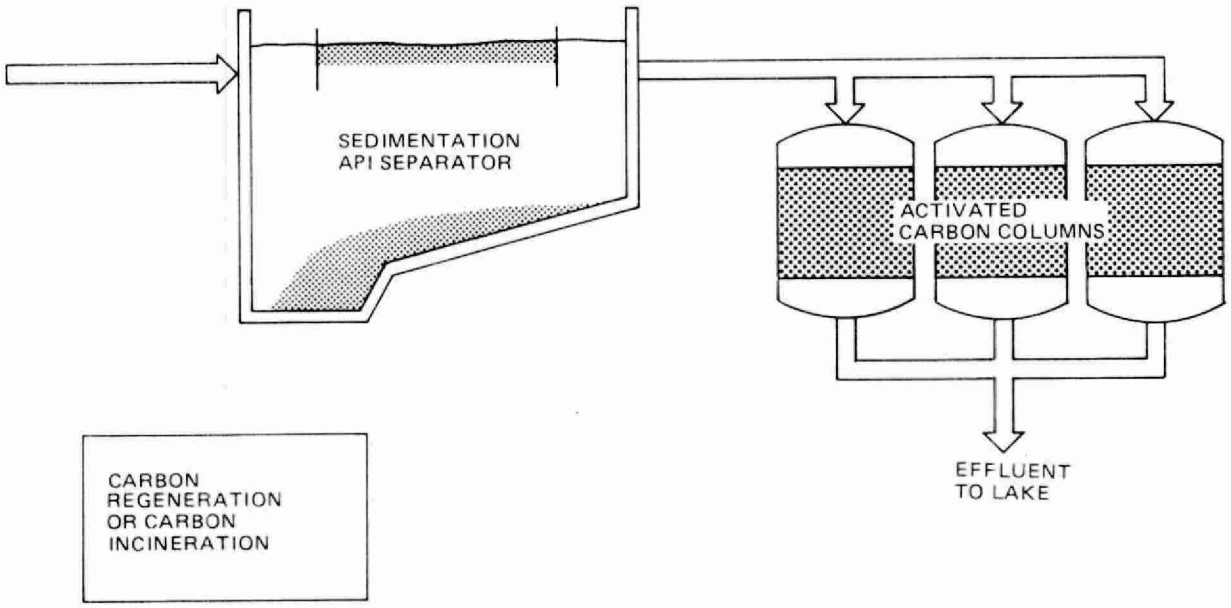
OZONATION

FIG. 10



PROPOSED TREATMENT PROCESS - ALT. 1 OZONATION

FIG. 11



PROPOSED TREATMENT PROCESS - ALT. 2 ABSORPTION

FIG. 12

PRETREATMENT OF VEGETABLE WASTEWATER AT THE H. J. HEINZ PLANT IN LEAMINGTON, ONTARIO

by D. Smit, Manager, Quality Assurance Dept.

The Heinz plant at Leamington has steadily increased its output of canned tomato products during the last few years. Also a considerable volume of fruits and vegetables such as peaches, pears, apples, peas, carrots and potatoes is processed. Several high starch - contents ingredients in the form of spaghetti, macaroni and beans also contribute to the B.O.D. loading of the wastewater stream leaving the plant.

The extended aeration system which was described in 1972 during the 19th Ontario Industrial Waste Conference has done an excellent job since its start-up in July/71. The waste water treatment plant consists of screening facilities, a 4 million gallon aeration basin with four 75 HP aerators and one 150 HP aerator and a 1 million gallon circular clarifier. The excess sludge is concentrated by centrifuging and is removed to sanitary landfill.

During our high B.O.D. loading times in August and September when we handle many thousands of tons of tomatoes, shockloadings in excess of 20000 lbs. of B.O.D. are successfully treated. After the 1974 season it was decided to add some form of pretreatment. We were having difficulty to maintain our D.O. level in the lagoon above the desired minimum of 1 ppm, as the tomato acreage was increased year by year. In 1969 and 1970 when pilot plant studies were run to establish design parameters for the present treatment plant, it was found that a roughing plastic media tower greatly reduced the B.O.D. contents of the waste water. Therefore we built such a tower during the spring of 1975 which has about 12000 cu. ft. of plastic media. My co-author Tom Eyre will discuss the engineering aspect of this project, such as construction details, selection of plastic media, capital and operating costs and performance data. The tower is a square of 32 X 32 ft. and has plastic media to a height of 12 ft. The ideal wetting rate we found was approx. 1.25 IG/ min./square foot or 1280 IG/min. Of this an average of 500 IG per minute was screened waste water and the balance was recycle (thus about 780 IG per minute). We try to keep the total waste water flow from the plant below 3 million Imperial gallons per day, therefore 25% of the total flow into the plant is pretreated to some extent in the tower. The average daily flow during the month of September 1977 was 1.979 M.I.G.D. or 1400 IG/min. so that on the average about 1/3 of the total influent was pretreated. However the critical time is during the periods of maximum flow as the retention time in the system then is in the neighbourhood of 36 hours.

As I mentioned before we pretreat about 25% of the total flow by feeding it over the tower. There only a part of the organic material is removed. For instance during August 1977 the C.O.D. was reduced by 40.9% and we found influent C.O.D. results of over 3000 ppm. This removal percentage however could not be maintained as we ran into an unexpected difficulty. During the last few years several new varieties of tomatoes have been developed which can be harvested mechanically. The percentage of mechanically harvested tomatoes has increased slowly. This type of tomatoes brings during harvesting some very fine sand into our flume systems and this sandy flume water eventually ends up into the pollution control centre. There it plays havoc with pumps, centrifuges and biomass which we so carefully built up on the plastic media during the start up of the treatment tower. This very fine sand effectively scours a portion of the slimelayers which we need as a medium for the bacteria. Therefore the average C.O.D. removal efficiency was 21.3% during the 1977 season when we ran the tower from July 22 to October 12. If we express the percentage in pounds C.O.D. removed of the total pounds of C.O.D. received at the pollution control centre then we averaged 9.4%. In order to reduce the quantity of fine sand in the influent we are presently installing a settling basin near the tomato fluming operation and also we are going to experiment with a swirl concentrator to remove the sand during this years tomato season.

The results even with the reduced C.O.D. removal efficiency (which we hope will improve to at least 30% from about 20%) were very encouraging and therefore another pretreatment tower now is under construction. This new facility will be 48 feet long 32 feet wide and will be filled with 12 feet high plastic modules. Therefore we will add 18000 cu. ft. of plastic media to the existing 12000 cu.ft. and hope we will be able to remove effectively the high peaks in our loadings.

This approach to pretreatment for our waste water with fairly high B.O.D./C.O.D. loadings is very flexible. We can start up a unit approximately one week ahead of expected peak loadings and have it in full operation when we need the extra removal capacity. Also from a capital investment standpoint this is a very favourable way of doing it. *Tom Eyre will now discuss the engineering and other details of our approach to pretreatment and upgrading of our pollution control centre.

(* T.E. Eyre, Chief Environmental Engineer, J.D. Lee Engineering Ltd., Brantford, Ont.)

Design Philosophy

Two alternatives were readily apparent. Either a second extended aeration type plant could be used with the existing system but, would require considerable over-design for future loads. The second alternative would be to introduce in a phased manner upstream, pretreatment ('roughing'), which would buffer the existing extended aeration plant in such a way that it would act as a polishing unit, not contributing excessive sludge for dewatering.

With regard to the first alternative, it would have been logical to install an identically sized unit to the existing extended aeration basin. As hydraulic flows were being kept at a constant level, the need for extra clarification would not have occurred, certainly in the short term. A likely cost for such an installation in 1974 was in the order of two million dollars.

The introduction of 'roughing' units would ensure that phased additions could be matched to meet future increased demands. It was desired that the new 'roughing' unit would operate with low maintenance. It was also desired that the unit, which would not be required for periods of the year could be brought onstream relatively quickly. It was desired that the land use of the new plant should be minimal as space was becoming a premium at the site. It was desired that the equipment design should accommodate B.O.D. load fluctuations, and to a lesser extent hydraulic differences. The system would be designed such that it would be a relatively simple matter at a similar stage to phase in future units. The selection of a plastic media tower to perform this function was made on the following grounds:-

1. At least fifty such units, treating food wastewaters, were in existence.

2. Design curves for this type of industrial waste were well authenticated.

3. Land space could be minimized.

4. The units could be operating at full performance within one week.

5. The overall energy requirements were some 40% less than that of an extended aeration system.

6. The tower would produce less sludge than the existing extended aeration plant per lb of B.O.D. removed.

7. The effluent from the tower would contain a significant (4-8 mg/L B.O.D.) oxygen input into the aeration basin.

8. Use of submerged sewer to the lagoon for influent feed meant that effluent could be recycled from the aeration basin at times of low or no flow.

For a high rate loading, open channel type packing is necessary. Three such forms are available in Canada, the blocks consist of alternate parallel sheets held together by either adhesives or by heat sealing along the external edges. In general, they weigh some 2 lbs. per cubic foot and have a total surface area of some 25-30 square feet per cubic feet. On a cost basis, the CIL product, 'Flocor' was selected. This is made of a 98:2% PVC:PVA Copolymer and consist of ten alternate flat and ten corrugated sheets stuck together by adhesive to form a nominal 4' x 2' x 2' block. The tower dimensions, if rectangular, are based on a multiple of four feet each way. The packing is stacked in layers in alternate directions. With 'Flocor' a maximun packed depth of twelve feet is recommended.

Design Criteria

The desired removal was set at 40% based on earlier test results. This required 1300 cubic feet of packing at a depth of twelve feet giving a cross section area 1083 feet square. The tower was selected to have a cross sectional area of 32' x 32'.

Design Flow	:	0.75 MIGD
Design BOD	:	650 mg/L
Design Loading	:	4900 lbs. B.O.D./D
Expected Removal	:	40% @ 10 lbs. B.O.D./yd^3/D.

Construction Details

A major advantage of plastic media is that it is light weight in nature and therefore, the structure that can be used to support and contain it, can be similarly of a light weight nature. The base slab is constructed of reinforced concrete. It is a slab on grade complete with a recycle pump suction trough. Reduction is spans is achieved by the use of intermediate supports on the base slab. The basic frame-work for the tower structure is that of hollow steel section, suitably capped, primed with coaltar epoxy. The skeleton in general is an external one with the inside face a skin of fibre reinforced plastic. All joints of the plastic are taped and a water tight structure is produced.

As the Heinz system was to be operated during the May to October period it was not considered necessary to winterize the system and therefore, open ports which can be seen from the following slide were maintained.

Water Distribution

It is our design practice to construct a rectangular tower and use fixed jet distributors. Various types of nozzles have been tried over the years, but an open bore jet upon a splash plate has been found to work consistently with low maintenance requirements. The tower has a ladder and cat walks at the top for inspection purposes.

Performance

Removal has been determined on a C.O.D. basis; the B.O.D. : COD ratio being some 63%. The following slide shows the removal of BOD as function of load at a varying hydraulic rates.

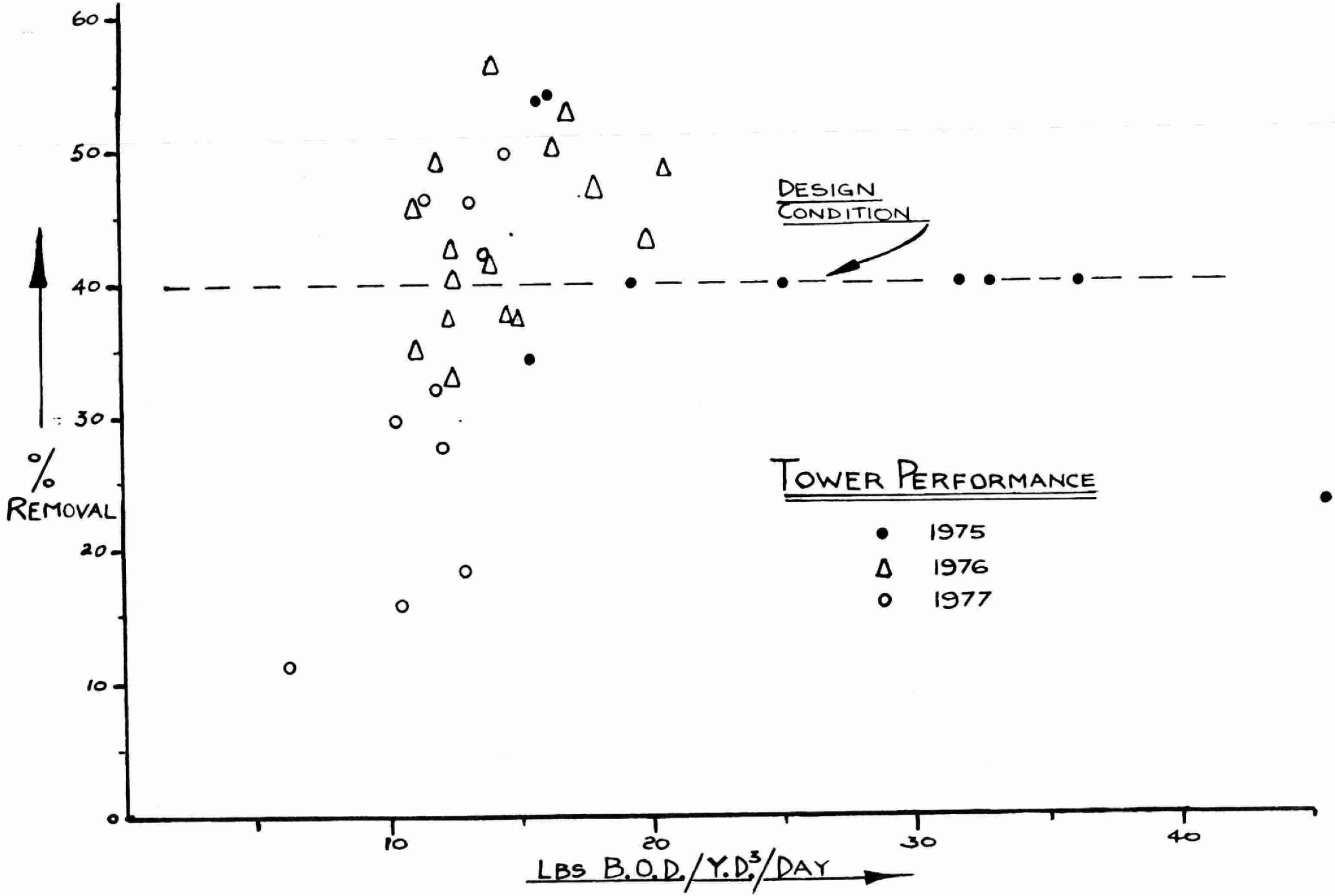
The interesting fact not shown is that in 1977, after some days of operation, the removal was 54%. This was some 10% over expected. As the volume of mechanically harvested tomatoes increased, the sand problem became acute. By August 30, 1977 a coating of sand had effectively stripped and choked the biomass, it also stopped the 120' diameter clarifier and "cleaned up" the centrifuges.

Cost Data

Competitive costings have shown plastic media towers as 'roughing' systems to be some 30-40% less expensive than an activated sludge system. For example, the tower at Heinz cost in 1975 some $75,000. The cost obviously is low because of the lightweight structure and small amount of civil works.

With regard to operating costs, manning costs are minimal; there being a need for a half hour inspection every other day. Power costs work out to be some 40-50% less than for mechanical aeration.

In conclusion, this hybrid system is to be recommended where limitations of land shortage, expenditure or speed of installation, control; it enables phased development to take place and these attributes, plus the performance of the system, have combined to convince H.J. Heinz to introduce the next phase of a larger complementary tower.


60
50
40
30
20
10
0
% REMOVAL
DESIGN CONDITION
TOWER PERFORMANCE
1975
1976
1977
10
20
30
40
LBS B.O.D./Y.D.³/DAY

TREATMENT AND RECOVERY OF EMULSIFIED OIL BY ULTRAFILTRATION

by

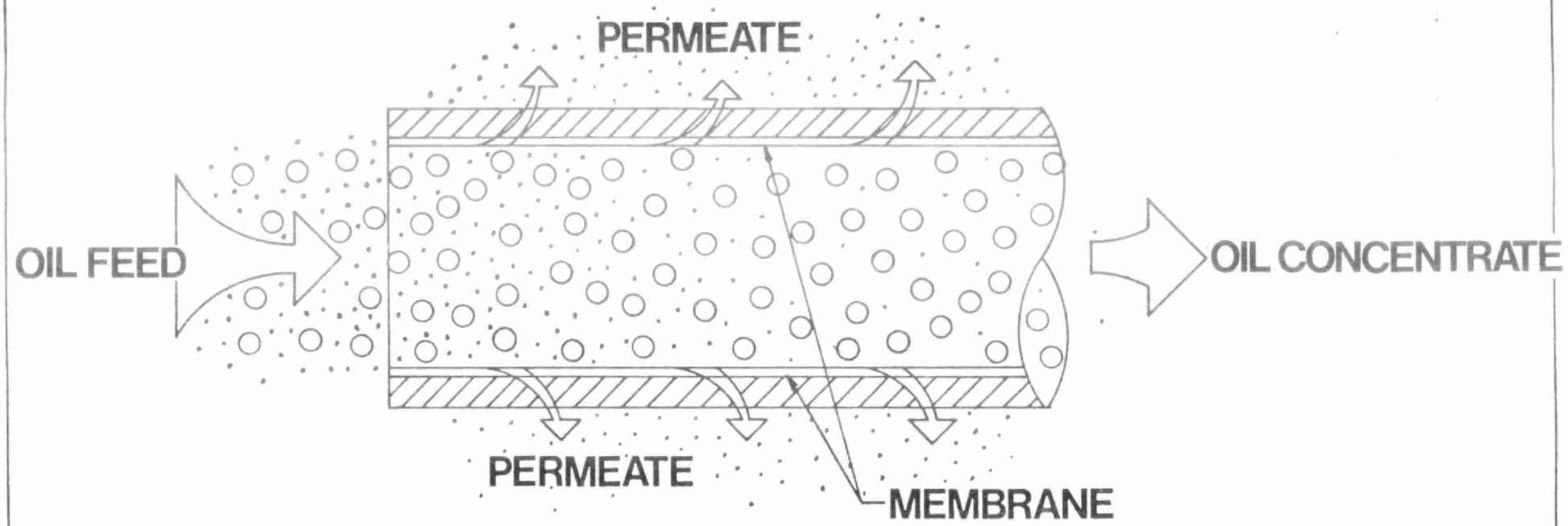
Gil Dhawan

Manager Reverse Osmosis

Electrohome Limited

Kitchener, Ontario

An Ultrafiltration plant developed, designed and installed by Electrohome Limited, Kitchener has been operating at Budd Automotive, Kitchener since October 1976. The production size plant treats oily water from the washers, where the drawing compound on the metal parts is removed by a misture of water and emulsifiers. The oil concentration of the oily water varies between 0 - 5%. The Ultrafiltration System continuously removes oil from the oily water and maintains the oil concentration in the washer under 5%. The concentrated oil from the Ultrafiltration System is allowed to settle in the settling tanks to give a final oil concentration of the recovered oil between 70 - 90%. The water from the ultrafiltration system contains most of the emulsifiers and is returned to the washers. Potential savings in oil, elimination of waste disposal costs and reduction in the washer clean-up, provide a payback of less than two years.



PROCESS OF ULTRAFILTRATION

- FIGURE 1

INTRODUCTION

Ultrafiltration is essentially a dewatering process and it consists of passing the liquid to be treated (feed) over a membrane surface. Generally, the flow of the feed is maintained at 80-160 liters/min at a pressure of 50-100 psi. This flow over the membrane surface causes the relatively pure water (permeate) to to go through the membrane whereas the feed becomes more concentrated in the retained substances and is removed from the system as a concentrate. It is important to note that there is no entrapment of the solids as in a mechanical filter or adsorption of any components as for instance, in carbon adsorption.

Membrane surface is kept clean by maintaining a highly turbulent flow of the feed so that the membrane can last for a long time. Membrane surface does require a regular cleaning cycle the frequency of which varies with the application and the system design.

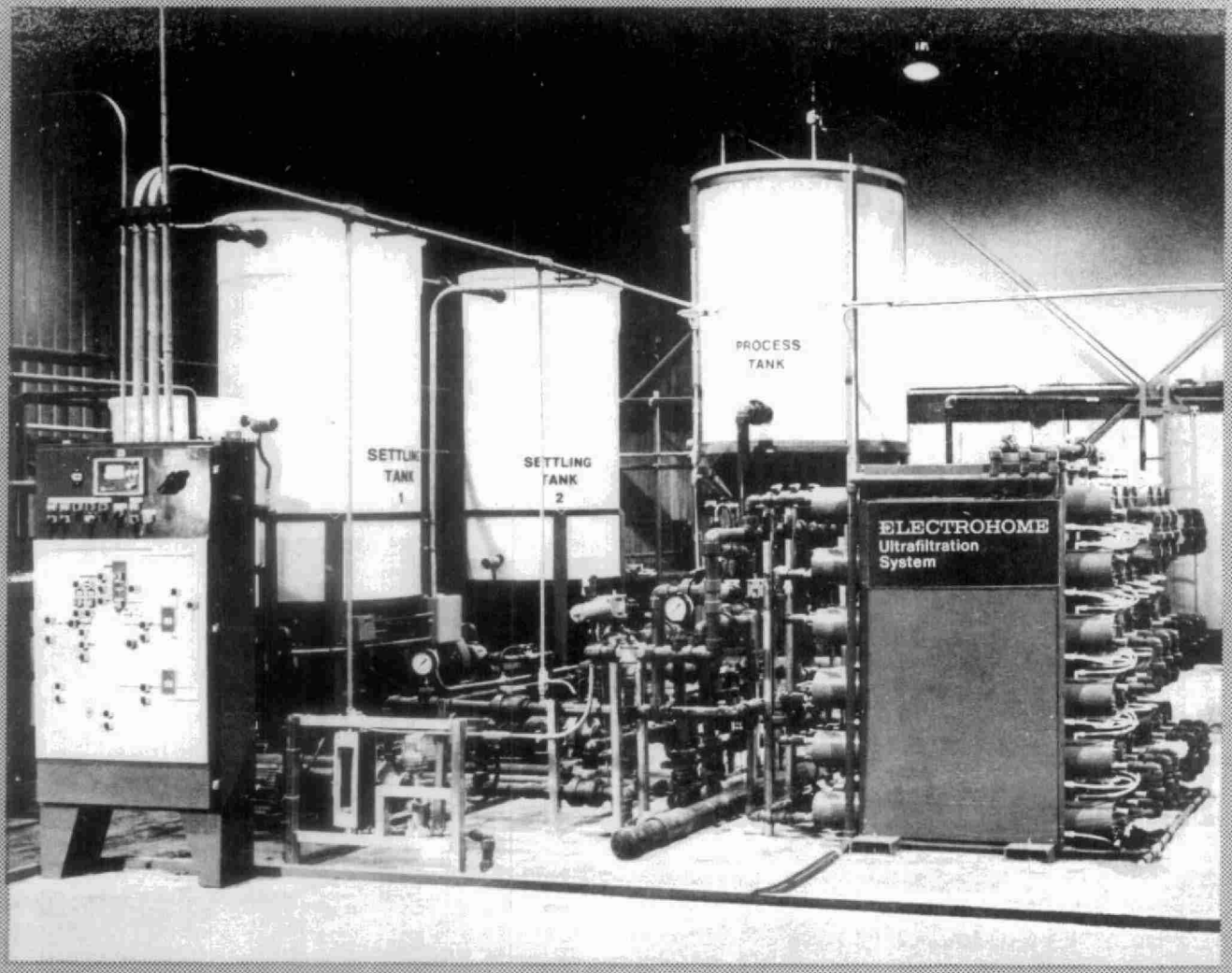
Ultrafiltration system requires only pump energy and in general, does not use any chemicals.

APPLICATION OF ULTRAFILTRATION TO EMULSIFIED OILY WASTE

Emulsified oily wastes are produced in metal working plants. These include machine shops, automotive plants, rolling mills and others. Emulsified oily waste is also produced in the textile industry. Most of these waste waters fall into the following classification:

Emulsified Oil content	1 to 10%
Typical Contaminants	Hydraulic and machine oils (unemulsified), metal fines, lint, dirt etc.
pH	7 - 12
Temperature	Ambient - 60°C (140°F)

Ultrafiltration System



Application: Soluble Oil Reclamation

In most cases it is relatively simple to remove unemulsified oils by using settling tanks, coalescers or other means that expedite the settling and separation process.

Emulsified oils, on the other hand, present a difficult waste treatment problem. The conventional treatment would include addition of acids, emulsion breakers etc. to break the emulsion and then follow it with a mechanical separation process similar to the ones mentioned for unemulsified oils. The oil recovered from these is of an inferior quality and normally can not be recycled back for its original use.

Ultrafiltration - a membrane process - can be used to dewater the emulsified oils very simply and effectively. The process is simple, continuous and there is a minimal use of chemicals. Also when the waste water contains only one type of emulsified oil, the recovered oil can be reused.

This paper describes one such system in operation at Budd Automotive, Kitchener, Ontario.

FACTORS AFFECTING THE PERFORMANCE OF THE SYSTEM

There are several factors that can affect the performance of the ultrafiltration system. These are listed below:

(1) Flow across the membrane surface - this is probably the most important variable in the system design. Higher the flow across the membrane surface, higher the permeate rate and lower the cleaning frequency. In actual practice the optimum flow rate is a compromise between the horse-power requirements for the pump and the increase in permeate rate.

(2) Cleaning of the membranes - the cleaning frequency of the membranes varies with the application and is dependent on the type and concentration of oil, emulsifiers and other additives, as well as the nature and concentration of contaminants, the degree of volume reduction required etc. A regular cleaning is essential to keep membranes at their peak efficiency.

(3) Oil concentration - the permeate rate is virtually independent of oil concentration of the emulsified oil up to a certain oil concentration. This concentration varies with each emulsion and is usually the point at which the emulsion breaks during the dewatering process.

(4) Operating Pressure - the operating pressure of the Ultrafiltration rarely exceeds 100 psi. The UF system must never be run at a pressure higher than the recommended pressure. Ultrafiltration membranes would have a permanent loss in thruput if subjected to higher than design pressures.

(5) Operating Temperature - this normally would be the highest temperature the membrane and the system can withstand. Membrane are now available in materials that can be steam cleaned.

(6) Unemulsified oils and other contaminants - the cleaning frequency of the membranes can be decreased by removing free oils and relatively large suspended solids by pre-settling and a coarse filtration. The free oils can be skimmed off from the pre-settling tanks and the emulsified oil can be processed by the UF System.

Careful design of the UF Systems with the above factors can reduce both the capital and the operating costs of the system.

PROBLEM

20,000 gallons of 5-10% oil dumped every two weeks.

Spray nozzles plug with oily sludge.

Large quantities of cleaning chemicals required in the washers.

FIGURE 2

ULTRAFILTRATION SYSTEM
PROCESS CONDITIONS

Average Pressure	50PSIG.
Temperature of the liquid	110°F.
Flow through 1" Dia. membrane tubes	25GPM
% Oil in Feed	1-5%

FIGURE 3

ULTRAFILTRATION SYSTEM DESCRIPTION

A schematic of the UF system is given in Figure 4. Wash water containing emulsified oil and the cleaning chemicals is pumped through a vibratory screen of 240 mesh to remove any contaminants such as lint. The screen system has an automatic steam clean cycle to stop blinding of the filter with the oil.

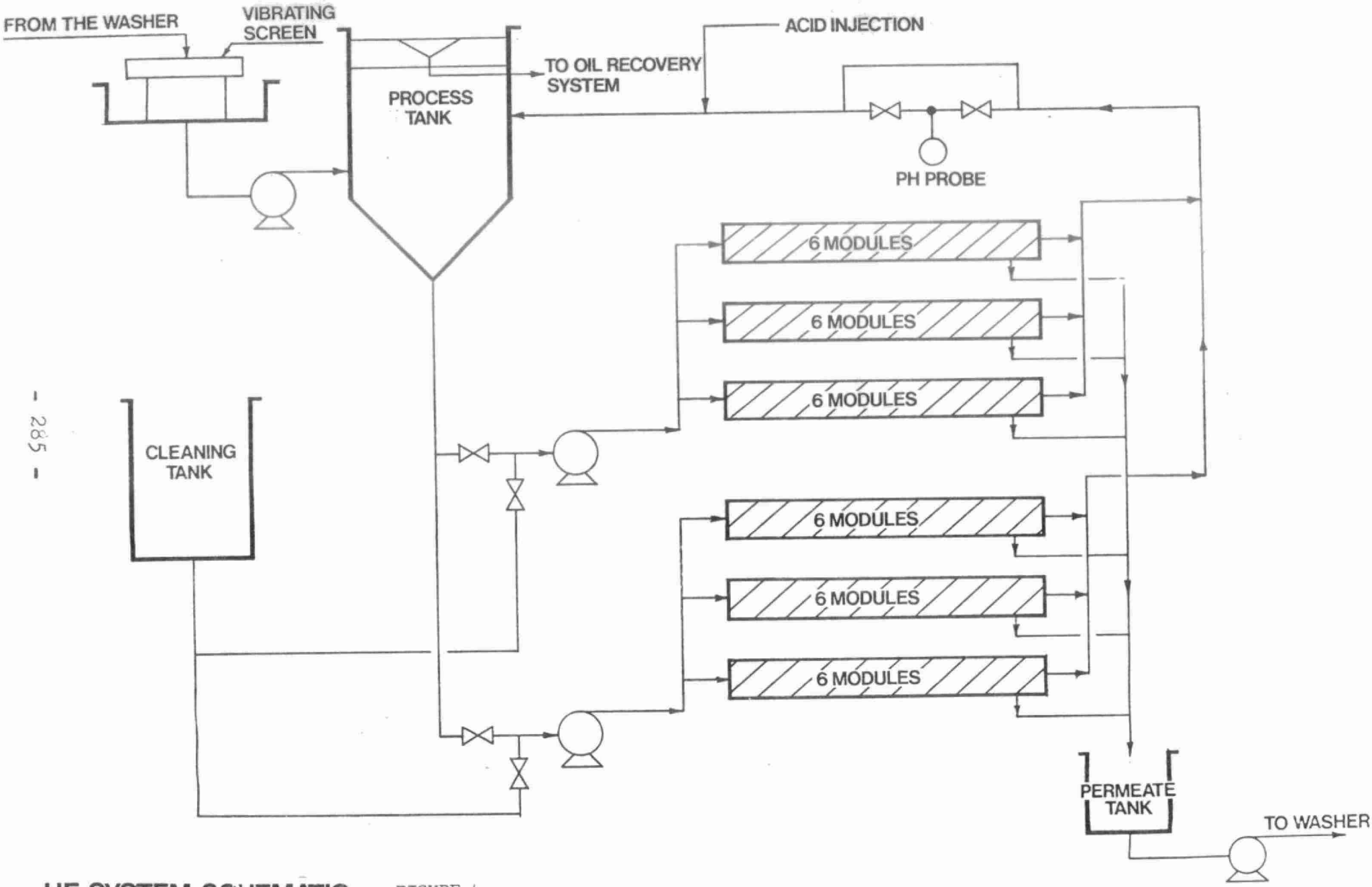
After screening the waste water is pumped to the process tank where a small amount of sulfuric acid is injected to bring the pH to around 7.

The ultrafiltration unit itself consists of two banks of modules. Each bank has 18 modules arranged as 3 parallel columns of six modules in series. A centrifugal pump for each bank pumps the liquid from the process tank through the modules. The pump flow is maintained at 80 GPM at an inlet pressure to the modules of 75 psi.

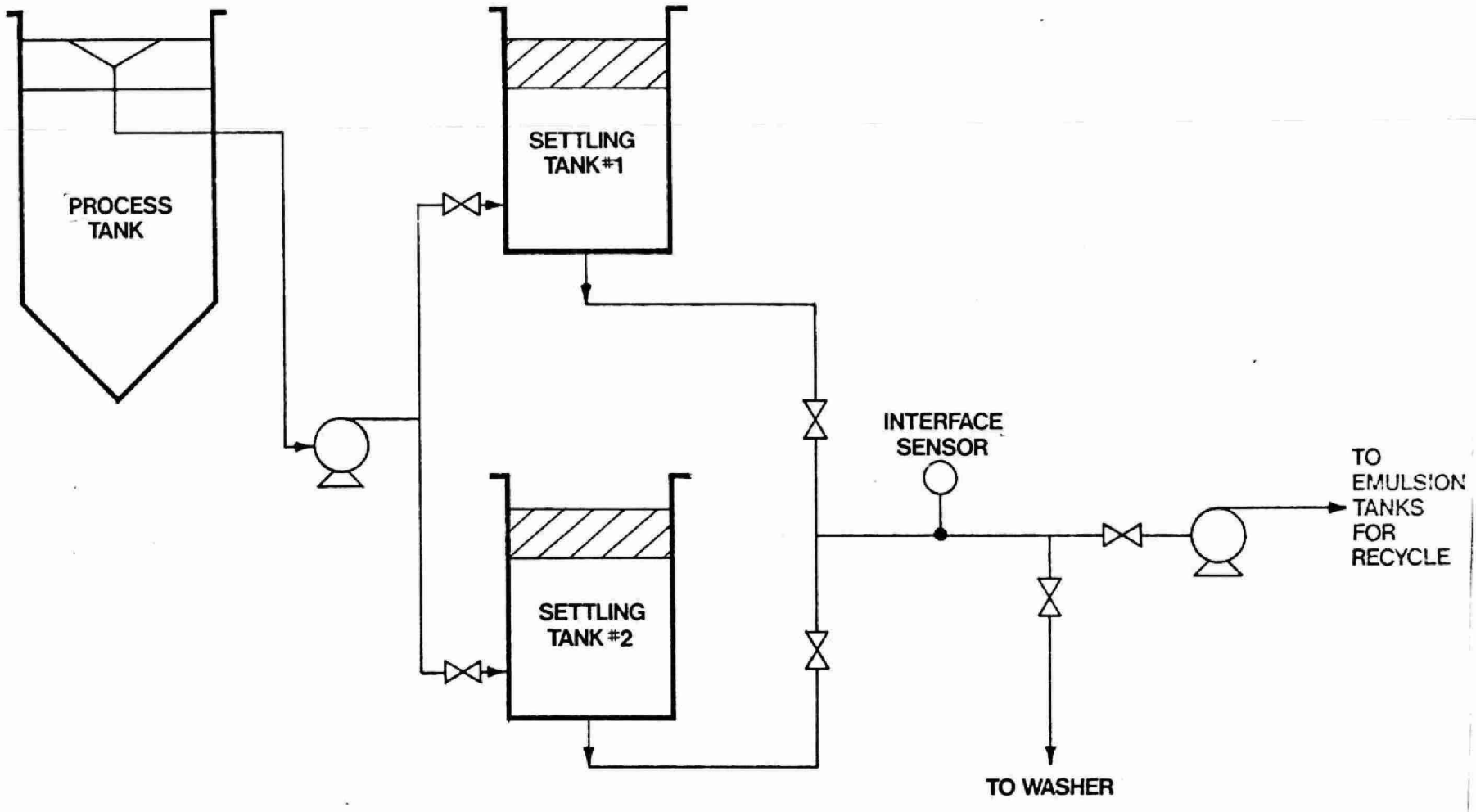
PERFORMANCE OF THE SYSTEM

The ultrafiltration system runs 24 hours/day and 7 days week. Daily monitoring includes checking the pH, permeate rate, gauge pressures, volume of concentrate removed and collecting samples of permeate, concentrate and feed for oil analysis.

Daily 3600 gallons of the washer water are treated by the UF-system to produce 3000 gallons of permeate containing some emulsifiers and the cleaning chemicals. This permeate is continuously returned to the rinse stage from where it overflows into the washer. The UF-system also produces 600 gallons of the concentrated oil. The concentration of the oil depends on several factors including oil concentration in the feed, amount of contaminants, amounts of cleaning chemicals etc. Normally the oil concentration of the concentrate is about 40%.



UF SYSTEM SCHEMATIC - FIGURE 4



OIL RECOVERY SCHEMATIC - FIGURE 5

The oil concentrate is transferred on a continuous basis to one of the two settling tanks. After about 24 hours the concentrate settles into two layers. The bottom layer contains mostly water and is fed back into the UF-system. The top layer containing between 50 and 90 per cent oil. This recovered oil is pumped to the emulsion tanks where a make-up package of additives is mixed with the recovered oil. The oil/water emulsion is then reused in the plant.

The permeate rate of the system decreases slowly with time due to gradual coating of the membrane surface with free oil and other suspended solids. The membranes can be cleaned by a cleaning cycle using a formulation that was developed for oily water applications. The cleaning mix must take into account the compatibility with membranes, the ability to remove contaminants in a relatively short time etc. It was concluded after operating the system for about six months that a weekly cleaning will be desirable for an optimum performance. Figure 8 shows the effect of cleaning on membrane performance.

ADVANTAGES OF THE ULTRAFILTRATION SYSTEM

The ultrafiltration system offers a number of advantages over conventional systems. Some of these are:

(1) The dewatered oil can be reused in the plant thereby allowing oil savings.

(2) The water can be recycled to the washers. This results in savings in water, energy and cleaning chemicals.

(3) A continuous removal of oil and suspended solids prevents a build up of sludge in the washer. The biweekly dumping and cleaning of the washer was reduced to once a year.

(4) There are further savings in chemicals because the oil level in the washer is maintained at a lower level at all times. Without a continuous oil removal, the amount of cleaning chemicals is increased as the oil level in the washer increases.

ULTRAFILTRATION SYSTEM
MATERIAL BALANCE

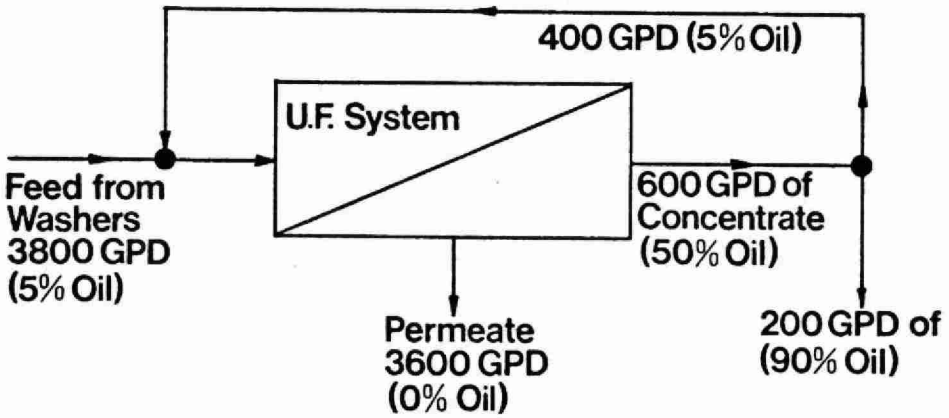


FIGURE 6

ULTRAFILTRATION SYSTEM

PERFORMANCE DATA

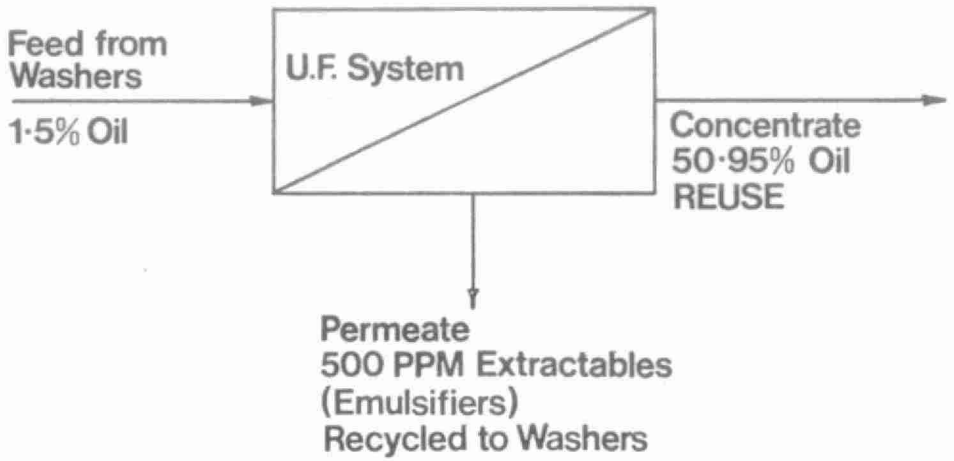


FIGURE 7

PERFORMANCE OF UF-SYSTEM AT BUDD AUTOMOTIVE, KITCHENER

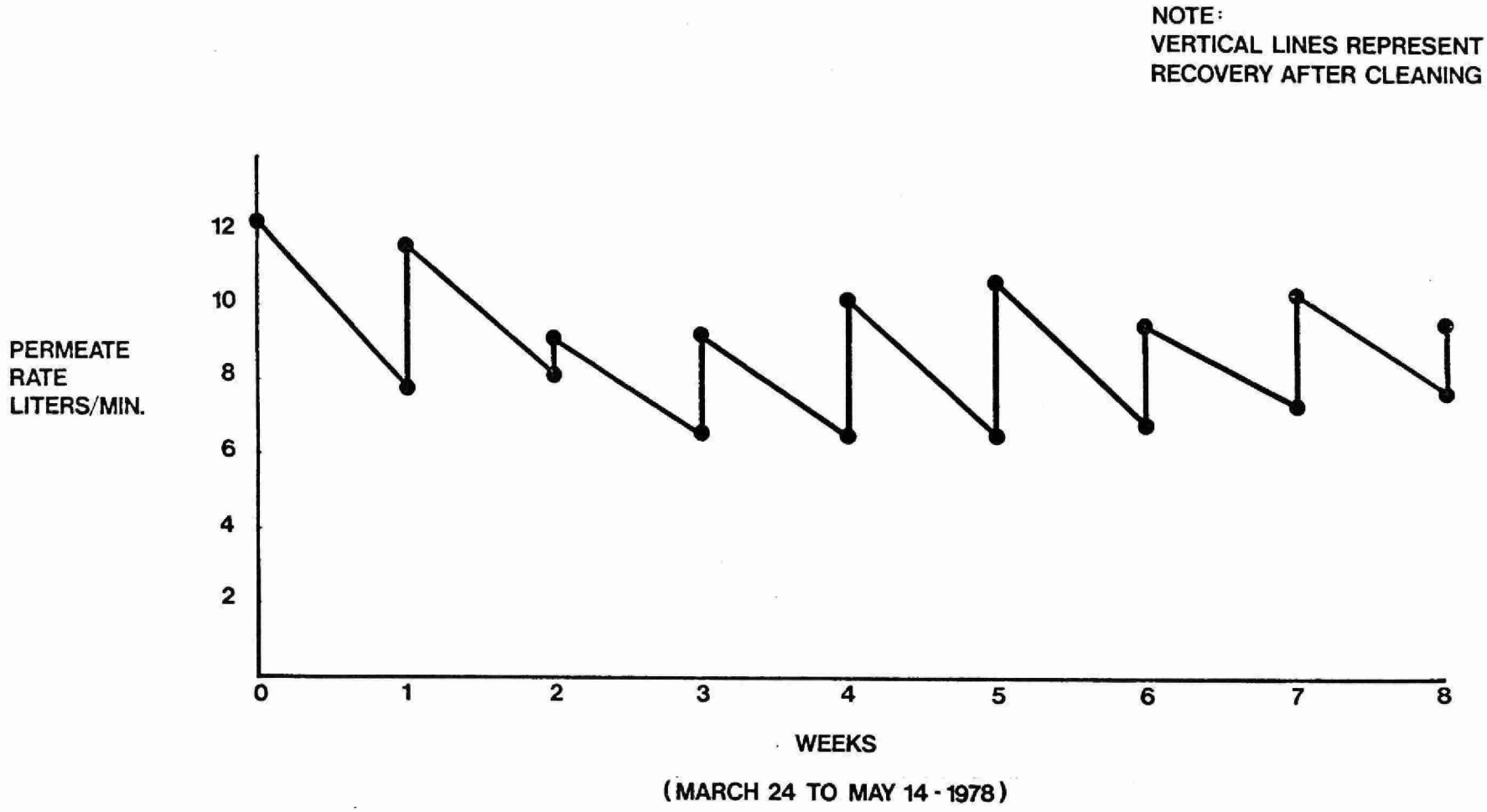


FIGURE 8

ECONOMICS OF THE ULTRAFILTRATION SYSTEM

The ultrafiltration system provides a number of cost savings. These are listed below:

(1) Yearly savings in drawing compound	-	$140,000
(2) Yearly cost reduction in washer cleaning	-	$ 70,000
(3) Yearly haulage cost of oily water	-	$ 60,000

In addition there are smaller savings in water costs, energy savings due to recycle of washer water at a higher temperature and chemical costs.

Also the downtime in the parts washing operation is virtually eliminated because the washer is no longer dumped.

Based on the above savings the payback time for the ultrafiltration system is less than six months.

CONCLUSIONS

Ultrafiltration can be used to dewater emulsified oily water. The process is simple and requires no chemicals. Where the oil can be reused the ultrafiltration process makes a closed loop system possible. The payback for the system is very attractive even when there is no recovery of the oil.

STAGED PRESENTATION
25TH ONTARIO INDUSTRIAL WASTE CONFERENCE
BANQUET, PRINCE HOTEL, JUNE 20, 1973

CAPLICE SIGNAL MAITRE D' TO CLEAR AND VACATE.

RANKIN DRUM ROLL - ATTENTION PLEASE, ETC.

——————→ QUIET. LOWER THE LIGHTS

SPOTLIGHT CAPLICE - GOOD EVENING LADIES AND GENTLEMEN. PLEASED TO WELCOME YOU TO THE ANNUAL BANQUET AND TO SEE SO MANY HAPPY FAMILIAR AND WELL-FED FACES.

SOME REMARKS ABOUT MURRAY CHEETHAM

THIS YEAR WE'VE CHANGED THE FORMAT TO RECOGNIZE OUR 25TH ANNIVERSARY. WOULD YOU BELIEVE THAT WE'VE BEEN ABLE TO BRING BACK ALL THE BANQUET SPEAKERS OF THE LAST 25 YEARS FOR A 4 HOUR PANEL DISCUSSION? IF YOU BELIEVE IT YOU'LL BE DISAPPOINTED.

INSTEAD, WOULD YOU COME WITH US AS WE WANDER LEISURELY AND NOSTALGICALLY THROUGH SOME OF THE RECEDING MEMORIES OF PEOPLE AND EVENTS THAT ARE MILESTONES IN THE HISTORY OF THIS CONFERENCE.

LET'S BEGIN BY RECOGNIZING AND THANKING SOME PEOPLE WHO HAVE GIVEN LONG AND VALUABLE SUPPORT TO THIS CONFERENCE.

KEEP SPOTLIGHT ON CAPLICE ADD SPOTLIGHT ON EACH SUCCEEDING AS FOLLOWS, EXPANDING LIGHT AS CAPLICE MENTIONS NAME.

JIM DUNCAN	1958	
MIN YATABE	1959	
BOB PARKER	1959	
JACK NORMAN	1960	
BILL SWANN	1960	
SID DUTTON	1961	(REPORTS HAS ATTENDED ALL SIN 1954)

BILL CASE

HUGH FIELDING

APPRECIATE THE FACT THAT YOU COULD BE WITH US TONIGHT.

- KILL SPOTLIGHT

SPOTLIGHT TOPIAS

EACH YEAR THIS CONFERENCE HAS BEEN HONOURED BY HAVING VARIOUS SPECIAL GUESTS. THIS YEAR IS NO EXCEPTION AND IT CERTAINLY IS AN HONOUR AND PLEASURE FOR ME TO INTRODUCE FOUR OUT-STANDING PEOPLE TO YOU.

SPOTLIGHT — HONOURABLE GEORGE MCCAGUE

SPOTLIGHT — HONOURABLE JAMES A.C. AULD

SPOTLIGHT — DR. JAMES A. VANCE

SPOTLIGHT — JOHN ROOT

- KILL SPOTLIGHT

SPOTLIGHT CAPLICE

SCRIPT OPENING

DENNIS — FOR 25 YEARS OUR CONFERENCES HAVE FOCUSED ON THE PROFESSIONALISM OF INDUSTRIAL WASTE TREATMENT. OUR FIRST CONFERENCE IN 1954 TOOK PLACE AT THE ONTARIO AGRICULTURAL COLLEGE IN GUELPH AND WAS SPONSORED BY THE POLLUTION CONTROL BOARD OF ONTARIO. THIS WAS A BODY OF SENIOR CIVIL SERVANTS APPOINTED BY THE THEN PREMIER, LESLIE FROST, WHOSE DUTY WAS TO REVIEW THE WATER POLLUTION PICTURE IN ONTARIO AND ADVISE THE GOVERNMENT OF THE COURSE OF ACTION NECESSARY TO SOLVE THE PROBLEMS.

DENNIS — THIS BOARD TOOK ITS RESPONSIBILITIES SERIOUSLY; IT STUDIED WATER POLLUTION IN DETAIL, HELD HEARINGS THROUGHOUT THE PROVINCE AND CONCEIVED THE INDUSTRIAL WASTE CONFERENCE.

DENNIS — ABOVE ALL ELSE, IT RECOGNIZED THAT INDUSTRIAL WASTE WAS AN EMERGING PROBLEM IN THE WATER POLLUTI FIELD.

LEN — AS FOR THE DELEGATES ATTENDING THESE EARLY CONFERENCES, PROBLEMS WERE MUCH MORE BASIC -- ONE MAJOR CONCERN BEING THE FACT THAT THEY WERE BILLETED ON THE UNIVERSITY CAMPUS AT GUELPH WHERE THE ACCOMMODATIONS FELL JUST A LITTLE SHORT OF THESE AT THE PRINCE. MOST OF THE GUYS FOUND IT WAS ALMOST IMPOSSIBLE TO LOCATE A LIQUOR STORE IN THE WHOLE CITY OF GUELPH IN THOSE DAYS.

LEN

BECAUSE OF THESE URGENT SOCIAL PRIORITIES, IT WAS UNANIMOUSLY AGREED TO PICK A LOCATION WHICH WOULD BE MORE ATTRACTIVE TO THE DELEGATES AND THE CONFERENCES MOVED TO THE DELAWANA INN AT HONEY HARBOUR FOR EIGHT YEARS...WHERE THE BOOZE WAS MORE READILY AVAILABLE.

DENNIS

BUT THERE WERE PROBLEMS AT DELAWANA -- ROOMS WERE IN SUCH SHORT SUPPLY THAT YOU AUTOMATICALLY HAD A COMPANION, AND YOU NEVER KNEW WHO THAT MIGHT BE, EVEN FROM NIGHT TO NIGHT. (LONG PAUSE, KNOWING SMILE). THE AIR CONDITIONING WAS A HUGE BLOCK OF ICE AND A FAN. OUR STAFF ALWAYS FOUGHT OVER WHO WOULD GET TO SHOW THE SLIDES. THE JUNIOR THAT YEAR USUALLY GOT STUCK ...AND SO DID THE SLIDES.

DENNIS

WE WERE VERY CONCERNED WITH ANNUAL ATTENDANCE FIGURES. DR. BERRY, USING HIS RENOWNED POWERS OF CREATIVITY AND PERSUASION REGISTERED ALL THE WAITRESSES, BUSBOYS AND CHAMBERMAIDS, IF IT LOOKED LIKE THE NUMBERS WERE FALLING SHORT.

DENNIS

DURING THIS PERIOD WE MADE GREAT STRIDES IN PRESENTING PROBLEMS AND SOLUTIONS ORIENTATED TO TECHNICAL CONSIDERATIONS AND IT BECAME THE BEST TECHNICAL CONFERENCE OF ITS KIND IN CANADA.

LEN

HOWEVER, THERE WERE STILL CERTAIN DRAWBACKS TO BEING ISOLATED IN THE RESORT SETTING. MOST OF OUR DELEGATES BECAME RATHER TIRED OF DANCING WITH THE WAITRESSES WHO WERE USUALLY INVOLVED IN DEMONSTRATING THEIR ABILITY OF THE NEW ROCK'N ROLL DANCES SUCH AS THE WATUSEE, THE CHICKEN, AND THE TWIST, TO THE BEAUTIFUL STRAINS OF "YOU AIN'T NOTHING BUT A HOUND DOG", "BONY MORONY", AND "BLUE SUEDE SHOES".

LEN

POST CONFERENCE BACK INJURIES WERE ENORMOUS AND REQUIRED ABOUT A WEEK OF RECUPERATION.

LEN

OUR PROBLEMS AS WE LOOK BACK, WERE QUITE SMALL WHEN YOU CONSIDER THAT IN THE '50'S THE CANADIAN FORCES WERE FIGHTING FOR PEACE IN KOREA, KASHMIR, INDO-CHINA, THE GAZA STRIP, THE CONGO, AND CYPRUS. OTHER GOVERNMENTS TALKED OF CANADA AS THE IMPORTANT MIDDLE NATION AND A DISTINGUISHED PEACE-MAKER.

DENNIS

TIMES WERE GOOD AND FOR THE FIRST TIME PEOPLE BEGAN TO BOAST OF TWO CARS IN THE GARAGE AND THERMOSTAT CONTROLLED HEATING IN THEIR HOMES. WE HAD COMPLETED THE WORLD'S LONGEST PIPELINE FOR OIL AND NATURAL GAS AND THE NATION'S LONGEST PAVED HIGHWAY -- THE TRANS CANADA.

DENNIS

THE GOVERNMENT ANNOUNCED PENSIONS FOR THE AGED, SUBSIDIES FOR DISTRESSED AREAS, INSURANCE PLANS AGAINST SICKNESS AND GRANTS FOR ANY STUDENT WITH THE ABILITY AND DESIRE TO ATTEND UNIVERSITY. THE GALS WERE WEARING BOBBY SOX, FOOTBALL SWEATERS, AND SADDLE SHOES. THE GUYS WERE GREASING BACK THEIR HAIR, (THE D.A.), WEARING DRAPED PANTS, AND DRIVING HOT RODS. THE DRIVE-IN RESTAURANTS PUT THEIR CAR-HOPS ON ROLLER SKATES, AND AT THE PASSION PITS IT WAS MARILYN MONROE, HUMPHREY BOGART, AND GREGORY PECK AND TELEVISION FEATURED LUCILLE BALL, ED SULLIVAN, UNCLE MILTIE, AND JACKIE GLEASON. THE SONGS OF THE DAY CAME FROM NAT KING COLE, FATS DOMINO, THE PLATTERS, AND THE "KING" ELVIS PRESLEY.

MUSIC COMES UP -- SEGMENT #1 OF STAGE PRESENTATION -- RECREATION OF THE MOODS OF THE '50's (12 - 14 MINS.)

BRIDGE NARRATION TO THE '60's

LEN

IN '64 AND '65, WE MOVED TO BIGWIN INN IN THE MUSKOKAS BUT BEING ON AN ISLAND IT TURNED OUT TO BE A LITTLE TOO ISOLATED AND HARD TO REACH. FURTHERMORE, AT THAT PARTICULAR TIME, THE HOTEL WAS SOMEWHAT RUN-DOWN. IT WAS APTLY NAMED HEARTBREAK HOTEL BECAUSE AGAIN, NONE OF OUR DELEGATES KNEW WHO THEY WERE GOING TO SLEEP WITH. BEING ON AN ISLAND NECESSITATED TAKING THE INFAMOUS BOAT RIDE TO AND FROM THE INN.

LEN

AND REMEMBER THE LITTLE TRIALS THAT PLAGUED US AT HEARTBREAK HOTEL. THE LOST LUGGAGE -- WE STILL DON'T KNOW WHERE IT WENT AND HOW IT GOT BACK, IF IT DID. AND NO HOT WATER ON THE SECOND FLOOR -- BRRR!

LEN

AND THE EMBARRASSMENT OF THE DECADE -- THE SEWAGE TREATMENT PLANT SERVING THE INN WOULDN'T WORK. DAVE CAVERLY CALLED OUT THE TROOPS FROM TORONTO TO INSPECT THE FACILITY, TEST THE WATER AND SEE WHAT WAS WRONG. NO WAY COULD THERE BE SUCH A SITUATION AT AN OWRC SPONSORED CONFERENCE. POOR DAVE, AS IF HE DIDN'T HAVE ENOUGH PROBLEMS. I GOT DYSENTRY AND HE HAD TO MAN THE REGISTRATION DESK AND SHOW THE SLIDES

DENNIS

FROM '66 TO '71 WE MOVED TO NIAGARA FALLS IN THE PARK MOTOR HOTEL AND THEN DOWN THE STREET TO THE SHERATON BROCK HOTEL BECAUSE IT HAD A LIQUOR STORE RIGHT IN THE LOBBY...NEEDLESS TO SAY THE SOCIAL SIDE OF THE CONFERENCE DEVELOPED SUBSTANTIALLY. WHILE MAINTAINING THE HIGH CALIBRE OF THE TECHNICAL PAPERS, WE ENCOURAGED THE ATTENDANCE OF THE LADIES AND THEY HAD THEIR OWN SOCIAL PROGRAMS. WE HAD DANCES, "HAPPY HOURS" AND OUTSIDE BANQUET SPEAKERS FOR A CHANGE OF PACE. YOU MAY REMEMBER THE REV. HARRY S. RODNEY FROM ST. THOMAS AND THE HUMOUR WHICH HE INTER-JECTED INTO THE CONFERENCE...OR THE FAMOUS "FOOD POISONING" AFTER ONE OF OUR ANNUAL BANQUETS WHEN, THE NEXT MORNING, EVERYBODY HAD THE "HOLLANDAISE TWO-STEP" AND WE WERE AFRAID TO GET IN OUR CARS FOR THE DRIVE HOME. THE NIAGARA FALLS SEWAGE PLANT WAS OVERLOADED FOR A PERIOD OF 12 HOURS.

DENNIS

THE SPACE AGE SIXTIES TOOK A "GIANT STEP FORWARD FOR MANKIND" AND EXPO '67 PROUDLY SHOWED "MAN AND HIS WORLD" AS A PLATFORM FOR THE GREAT MEN OF THEIR ERA...THE KENNEDYS, MARTIN LUTHER KING, WERNER VON BRAUN, LESTER B. PEARSON, AND WALT DISNEY.

LEN

WOMEN'S HEMLINES ROSE TO THEIR THIGHS, MEN'S HAIR DROPPED TO THEIR SHOULDERS, AND THE DAY OF THE HIPPIE, YIPPIE, THE DRUG CULTURE, AND COMMUNAL LIVING WAS BORN.

LEN

JULIE ANDREWS SANG TO THE HILLS IN THE SOUND OF MUSIC AND JULIE CHRISTIE AND OMAR SHARIFF IN DR. ZHIVAGO MADE THEIR CONTRIBUTIONS TO CONSERVATION, WHEN THEY SHOWED US HOW TO KEEP WARM WHEN IT'S 60 BELOW. WAS IT A MUSICAL ZOO WITH THE BEATLES, THE MONKEES, AND THE ANIMALS,??? THE KIDS DANCED THE MASHED POTATO, THE JERK, THE CHICKEN, THE PONY; AND CHUBBY CHECKER INTRODUCED THE TWIST... BUT THERE WAS ALSO SOME SANITY WITH PERFORMERS SUCH AS NEIL DIAMOND...

MUSIC COMES UP -- SEGMENT #2 OF STAGE PRESENTATION --- RECREATION OF THE MOODS OF THE '60's (12 - 14 MINS.)

BRIDGE NARRATION TO THE '70's

DENNIS

IN 1972 WE MOVED THE CONFERENCE TO TORONTO AS WE REALIZED WE HAD REACHED A CREDITABLE RESPECTABILITY IN REGARDS TO THE HIGH CALIBRE OF PEOPLE CONTRIBUTING TO THE CONFERENCE. BUT YOU KNOW THINGS REALLY DIDN'T CHANGE THAT MUCH...A FEW OF US STILL COULDN'T FIND THE LIQUOUR STORE. SOME COULDN'T EVEN FIND THE HOTEL BECAUSE IN THOSE DAYS WE WENT TO THE SKYLINE AND THERE WAS A LOT OF CONSTRUCTION IN THE AREA. ONE OF THE NEW PROBLEMS WAS THE SIZE OF THE HOTEL. SO MANY MORE PEOPLE AROUND WITH UNTOLD PARTIES AND RECEPTIONS GOING ON ALL THE TIME. IT WAS TOUGHER TO KEEP THE SESSIONS WELL ATTENDED, BUT WE DID IT. IT WAS TOUGHER TO MAINTAIN A TECHNICAL PROGRAM OF HIGH CALIBRE BUT WE DID IT. JUST RUNNING THE CONFERENCE OVER THE YEARS PRESENTED TOUGH NEW PROBLEMS ALL THE TIME.

DENNIS

I'M SURE YOU'LL WANT TO JOIN WITH ME IN EXPRESSING OUR WARMEST THANKS TO THOSE PEOPLE WHO HAVE BEEN ORGANIZING AND RUNNING THIS CONFERENCE OVER THE YEARS.

DENNIS

DR. A.E. BERRY
CHAIRMAN 1954 - 1962

D.S. CAVERLY
SECRETARY 1954 - 1962, CHAIRMAN 1963 - 1973

K.H. SHARPE
CHAIRMAN 1974 - 1976

MAE GROVE
CO-ORDINATOR 1954- 1962

L.M. TOBIAS
CO-ORDINATOR 1963 - 1973

M.J. CATHCART
CO-ORDINATOR 1974

F.A. VOEGE
PROGRAM CONVENOR 1960 - 1973

LEN

LET'S NOT FORGET THE PRESENT MEMBERS OF THE CONFERENCE PLANNING COMMITTEE:

DENNIS CAPLICE
CHAIRMAN 1977 AND 1978

JOHN PATTERSON
PROGRAM CONVENOR 1974 - 1978

MURRAY CHEETHAM
CO-ORDINATOR 1975 - 1978

ED TURNER
COMMITTEE MEMBER 1976 - 1978

LEN

AND SPECIAL GUEST - JACK SCOTT - CONFERENCE PROMOTIONALIST FOR 15 YEARS.

DENNIS

AND NOW THAT WE HAVE PAID TRIBUTE TO THOSE WHO GOT US ALL STARTED 25 YEARS AGO, LET'S GET BACK TO THE SCRIPT AND THE SHOW FINALE.

LEN

YES IT'S THE '70'S...THE END OF AN EPOCH CALLED VIET NAM AND THE START AND FINISH OF ANOTHER NIGHTMARE CALLED WATERGATE...AND IN CANADA THE WAR MEASURES ACT IS ENFORCED DURING THE F.L.Q. CRISIS IN QUEBEC. IT'S THE TIMES OF BIG MARRIAGES: TINY TIM AND MISS VICKY, PIERRE AND MARGARET, HENRY AND NANCY..ANNE AND MARK AND ELIZABETH TAYLOR DID IT AGAIN, AND AGAIN AND AGAIN...

LEN

THERE'S WOMEN'S LIB, THE ENERGY CRISIS, SOARING PRICES, WAGES AND INFLATION...BANKS WILL MAKE LOANS FOR ANY GOOD REASON INCLUDING GROCERIES. BUY STEAK AS AN HEDGE AGAINST INFLATION.

DENNIS

AMERICA FALLS IN LOVE WITH A PEANUT FARMER FROM THE SOUTH. RYAN O'NEILL FALLS IN LOVE WITH ALI MACGRAW IN LOVE STORY...RICHARD NIXON FALLS IN LOVE WITH HIMSELF AND GERALD FORD JUST FALLS.

DENNIS

THERE'S PERVERTED VIOLENCE AS STRAW DOGS AND CLOCKWORK ORANGE GIVE WAY TO NEW FORMS OF MOVIEW MAYHEM IN THE EXORSIST, DEEPTHROAT, JAWS, AND STAR WARS.

DENNIS -

IT'S THE DAY OF THE DISCO, BUT PAUL ANKA, BOBBY VINTON, AND NEIL SEDAKA MAKE COMEBACKS... BECAUSE AS TIMES GET TOUGH THERE IS A NOSTALGIC DESIRE TO RETURN TO "THE WAY WE WERE".

MUSIC COMES UP -- SEGMENT #3 OF STAGE PRESENTATION --- RECREATION OF THE MOODS OF THE '70's (12 - 14 MINS.)

DENNIS

SHOW TERMINATES -- BREAK AND CLEAR THE ROOM -- PAY BAR IN THE FOYER -- RETURN FOR DANCING TO MIDNITE TO BERT RENKIN AND "THE ELASTIC BAND".

BOWS FOR BERT RANKIN AND TROOP -- (PER BERT)

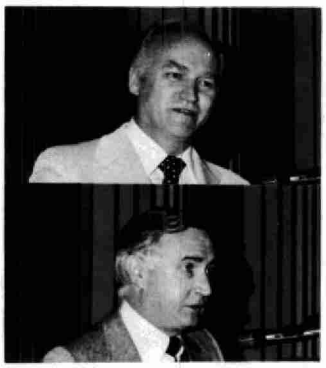
BARBIE CAMERON
THE NITE STAR DANCERS - LIZ WITIUK
- JEANETTE MCPARTLAND
AND THE ELASTIC BAND

SESSION V

Chairman: R. M. Gotts, Acting
Regional Director,
Northwestern Region,
Ontario Ministry of the
Environment,
Thunder Bay

Pollution Prediction Techniques for Waste Disposal Siting — A State-of-the-Art Assessment
R. A. Landon, Manager,
Earth Sciences Department,
Roy F. Weston,
Environmental Consultants,
West Chester, Pennsylvania

Facilities Using New Technology to Treat Toxic Pollutants
C. T. Tiller,
Director, Marketing/Sales,
SCA Services Inc.,
Boston, Massachusetts



The Year of New Respect for Waste Management
T. W. Drew, President,
D & D Group,
St. Catharines, Ontario

Preparation and Conduct of Environmental Hearings Before the Environmental Assessment Board of Ontario
M. P. Forestell, Q.C.,
Senior Partner, Forestell, Talmage & Hugill, Welland, Ontario

Solidification of Wastes
D. Krofchak, President,
Canadian Waste Technology Inc.,
Markham, Ontario

POLLUTION PREDICTION TECHNIQUES FOR WASTE DISPOSAL SITING
A State-of-the-Art Assessment

by

Ronald A. Landon, CPGS

Introduction

Scope and Objectives. Passage of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) has mandated the restoration and protection of the quality of our Nation's surface waters, which will result in the decrease of a number of point-source discharges of wastes directly into streams. A significant potential for adverse impact on the Nation's groundwaters now exists due to this increased land disposal of solid and liquid residual wastes, particularly hazardous wastes.

Concurrently, there has been an increase in the amount of waste being generated, and many wastes continue to be disposed of in a "least-cost" way which contributes to environmental degradation. Landfilling, ponds, lagoons, and other indiscriminate land-disposal methods have proven in numerous instances to be ineffective for adequate protection of the health of both the public and the environment, particularly where hazardous wastes are involved. This can also be attributed to poor management practices, since technological and management guidelines regulating such disposal practices have, for the most part, been only recently enacted. With respect to hazardous wastes, a number of state regulatory agencies have only recently initiated the writing or adoption of such guidelines.

Sub-title C of the Resource Conservation and Recovery Act (RCRA) of 1976 (PL 94-580) will regulate hazardous waste on a national level for the first time. Section 3004, Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities, and Section 3005, Permits for Treatment, Storage, or Disposal of Hazardous Waste, deals specifically with the disposal aspects of hazardous wastes. In order for such regulations to be effective, technologically-sound pollution prediction techniques of a national, uniform nature must be used for the siting of waste disposal and management facilities.

Techniques which would predict the potential for groundwater pollution prior to the disposal of specific wastes at specific sites would be a useful tool for regulatory and enforcement agencies. However, contradictory expert opinion exists relative to the mechanisms and effectiveness of attenuation processes for waste renovation which are an integral part of the land-disposal/land-treatment process. This, in turn, has inhibited effective and consistent decision-making for determining the confidence with which one can dispose of a specific waste at a specific site.

The overall objective of this investigation is to provide a state-of-the-art assessment of pollution prediction techniques for waste-disposal siting. This assessment includes both current research and regulatory procedures relative to the land disposal/treatment of waste for the entire waste spectrum, exclusive of radioactive wastes. The emphasis, however, will be on that research and those regulatory procedures that deal specifically with hazardous waste. Furthermore, the emphasis is to be on those techniques which lead to pollution prediction through an assessment of attenuation of waste leachates.

Key specific objectives of this investigation are as follows:

1. Conduct interviews with acknowledged experts in the field of waste attenuation/management to assess current laboratory and field research techniques relative to pollution prediction and with selected domestic and foreign regulatory agencies to assess current regulatory procedures utilized for waste disposal siting, with emphasis on hazardous waste disposal.

2. Identify and assess the state-of-the-art of techniques to both predict and describe the pollution potential from specific wastes disposed of at specific sites.

3. Identify and assess the most useful water/soil/waste interaction and attenuation mechanisms which are indicative of the ability of a potential site to accept a specific waste for land disposal/treatment in an environmentally-safe manner.

4. Prepare detailed development plans for those techniques which best predict the groundwater pollution potential and the suitability for permitting of land disposal/treatment sites for both the short-term (within three years) and the long-term (within ten years).

Literature Search. A literature search was conducted to identify pertinent references on the behavior of contaminants in subsurface environments. A major portion of the literature search was conducted using the computerized Lockheed Dialog Retrieval Service. Additional references were obtained during expert interviews throughout the project.

A general discussion of literature search methodology can be found in Section III of this report. Specific discussion on related work and research can be found in Sections IV, V, and VI and in Appendix A of this report.

Processes Influencing Mobility and Attenuation of Chemical Waste Constituents in Soil-Water Systems

The soil is a dynamic system in which numerious chemical, physical, and biological reactions occur singly or simultaneously with time. Soil, under normal conditions, is able to transform or stabilize some hazardous constituents to equilibrium soil components.

For the purpose of this study, "attenuation" is defined as: "Any physical, chemical, and/or biological reaction or transformation occurring in saturated and/or unsaturated zones that brings about a temporary or

permanent decrease in the maximum concentration or in the total quantity of an applied chemical or biological constituent in a fixed time or distance traveled."

Attenuation Mechanisms. The attenuation mechanisms can be categorized as physical, chemical, or biological. A description of the important mechanisms follows.

Physical Processes

1. Molecular diffusion is a spontaneous process resulting from the natural thermal motion of dissolved substances. This is generally considered an insignificant transport process; however, it modifies abrupt concentration differences between solutions of different concentrations in contact with one another.

2. Hydrodynamic dispersion is the result of variations in pore water velocity vectors within the soil. As shown in Figure 1, it tends to spread or reduce abrupt concentration changes in the soil with time. The process is effective in attenuating the maximum concentration of a pulse or slug of waste with time and distance as it moves through a soil profile.

3. Dilution of leachate by soil moisture and groundwater can provide effective attenuation of a given contaminant.

Chemical Processes

1. Adsorption-desorption or ion exchange influences the mobility of a hazardous constituent. When the reaction is reversible (which is generally the case for cation exchange), the attenuation is only an apparent one resulting from a reduction in constituent mobility. Figure 2 illustrates the influence of adsorption-desorption on constituent concentration distribution in the soil-water phase and compares it with a non-adsorbed constituent.

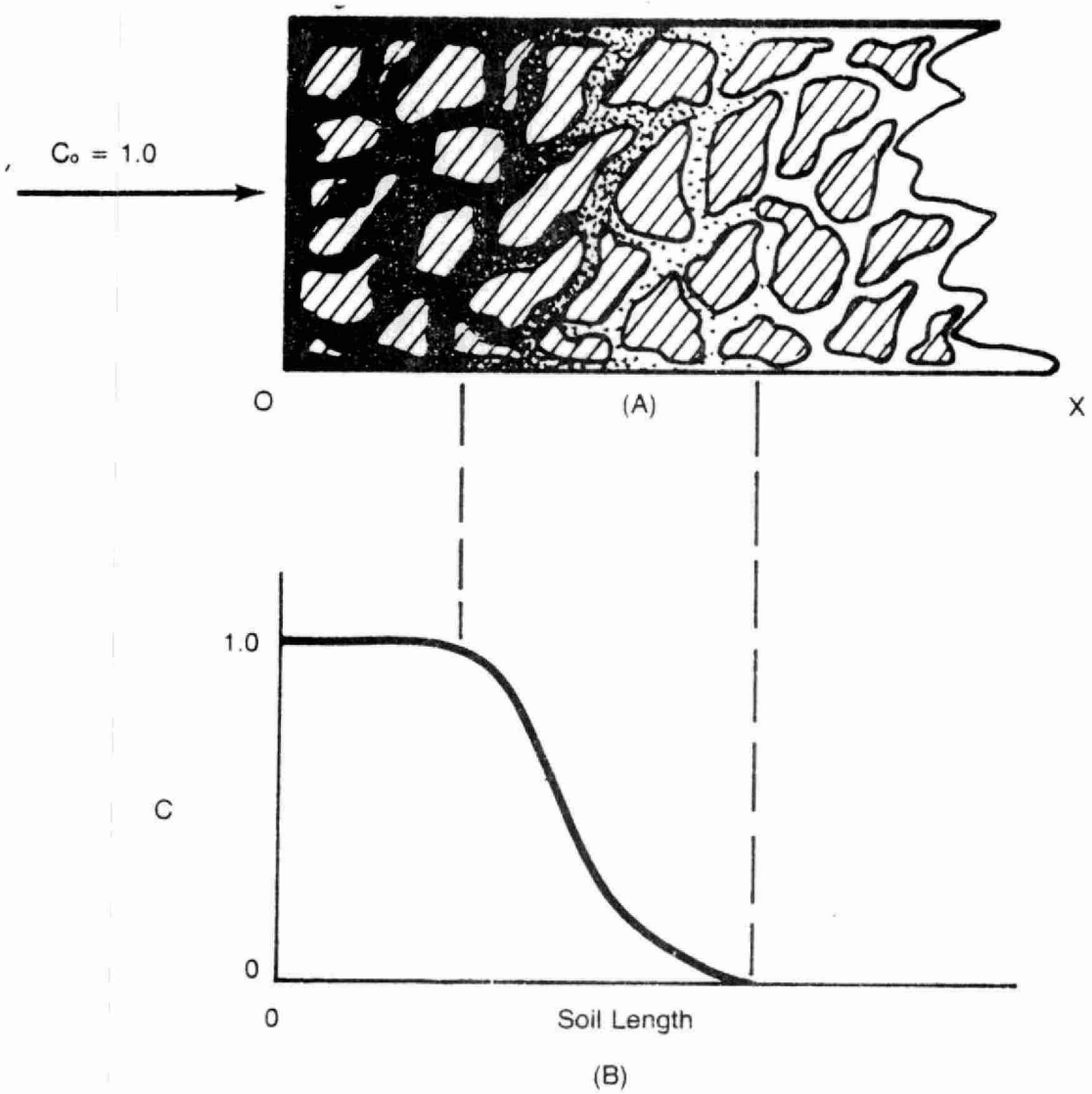


FIGURE 1 ATTENUATION BY DISPERSION:

(A) The crosshatched areas are soil particles, the solid area represents a soil solution with a constituent concentration of C_o and white area represents a soil solution with a constituent concentration of zero.
(B) Average constituent concentration distribution in the soil as a function of soil length.

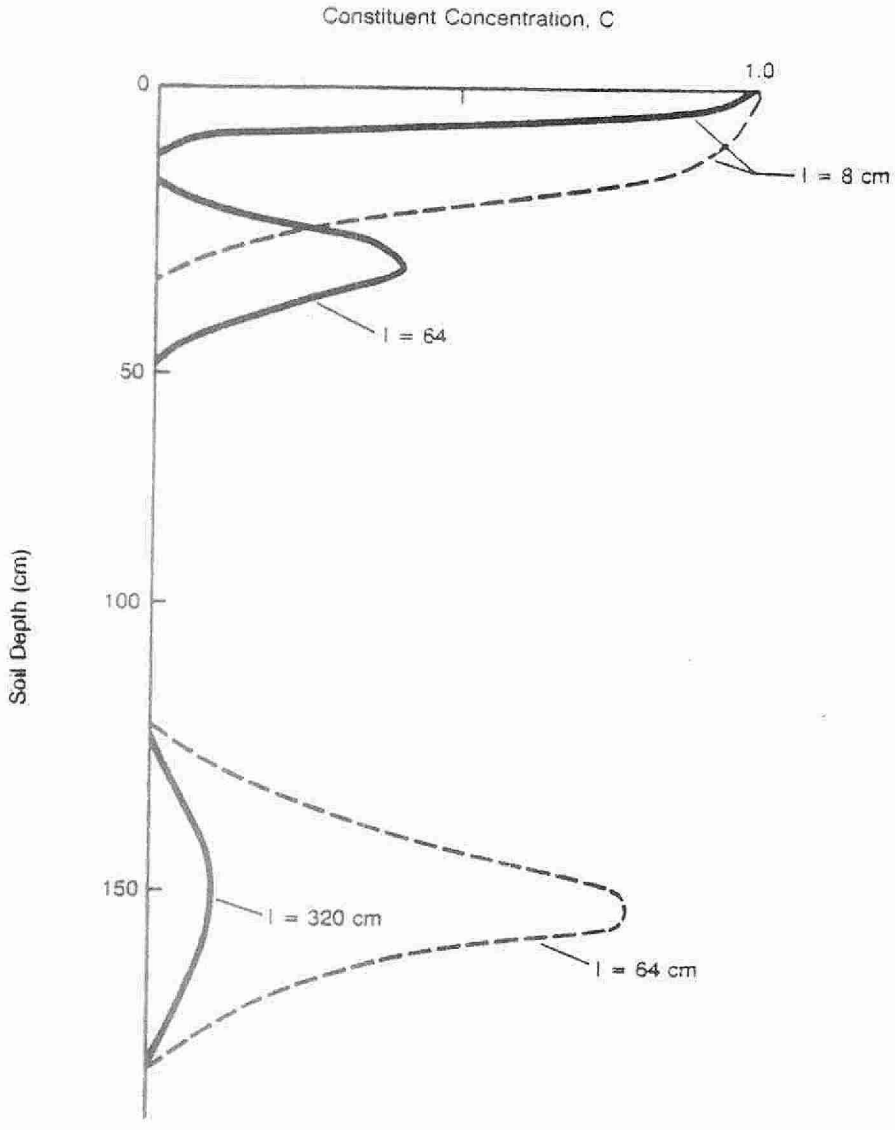


FIGURE 2 DISPERSION OF CONSERVATIVE AND NON-CONSERVATIVE IONS:

The solid line represents a constituent that exchanges with cations on the soil solid phase and the dashed line represents a conservative constituent such as chloride. The water content of the soil is 0.4 cm^3/cm^3 and the constituent concentration in the solution entering the soil is 1.0. The amount of solution that has been added at the soil surface is represented by I. The initial eight cm of solution entering the soil contained both contituents, whereas that which followed contained neither constituent.

2. Precipitation, as adsorption, involves the removal of a constituent from the soil water. Changing the constituent from a soluble to an insoluble phase reduces both the maximum as well as the total amount of constituent in the soil-water phase. This reaction is pH dependent and often occurs simultaneously with adsorption, which makes it difficult to separate the two processes.

3. Oxidation-reduction reactions influence the mobility and attenuation of constituents (especially trace and/or heavy metals) and are often initiated by biological activity. Oxidized constituents are less mobile than the reduced forms of the constituent, and reduced soil conditions contain more soluble constituents than the oxidized soil environment at the same soil pH.

Biological Processes (Biodegradation). Micro-organisms (e.g., bacteria, actinomycetes, fungi and algae, are an integral part of the soil. They transform wastes by such processes as oxidation, reduction, mineralization, and immobilization. The end products of these transformations are generally harmless, but some toxic metabolites have been produced.

Sufficiency of Attenuation. The degree of attenuation required for a waste constituent is generally based upon the maintenance of an acceptable groundwater quality. This is dependent on the amount and concentration of waste constituents and groundwater quality objectives. In general, no single process or reaction (physical, chemical, or biological) is responsible for the total observed attenuation of a waste constituent.

Several factors play key roles in attenuation. These include: waste quantity, potential for infiltration, type and concentration of contaminants in leachate, rate of leachate migration from the disposal site, and mass transport of the constituent in saturated and unsaturated media at the vicinity of the disposal site.

Pollution Prediction Techniques

Interviews were conducted with more than 40 non-regulatory experts in various professional disciplines relative to assessment of the attenuation of waste leachates and the development of pollution-prediction techniques. Numerous research endeavors have either been completed or are currently in progress. A summary assessment of those categorical techniques is given below, with a more detailed assessment found in the main report and its appendices.

Interviews were conducted with selected regulatory agencies to identify the decision procedures currently being used in the permitting (or rejection) of waste-disposal operations. It must be emphasized that many wastes categorized as hazardous wastes are not permitted for disposal with reliance on attenuation. It became readily apparent in the course of this investigation, therefore, that the presently used techniques which do not emphasize attenuation would also require inclusion and assessment.

Those pollution prediction techniques identified to date and assessed in this report can be categorized as follows:

- Criteria Listing
- Criteria Ranking
- Matrix
- Classification System (Decision Tree)
- Models (Mathematical)
- Laboratory Simulation (Column Studies)

It should be noted that a number of these techniques are interrelated (e.g., Criteria Listing with each of the others) or constitute "sub-routines" within a more encompassing decision-making technique (e.g., column studies and the Classification System).

Criteria Listing. The most basic and universally-applied identified is that of Criteria Listing. This approach was found to be used to a varying degree by each of the domestic and foreign regulatory agencies contacted.

The Criteria Listing approach consists of listing factors for both waste and site characterization and of obtaining data to adequately define each factor listed. An assessment of these data is then made by the review personnel on the basis of their level of expertise, the empirical data base gathered, and by comparison with pertinent appropriate examples.

The basic elements of the Criteria Listing approach are as follows:

- Waste characterization: type, amount, physical characteristics, chemical characteristics, and biological characteristics.

- Site characterization: location, topography, climatology, land use, soils, geology, and hydrology.

Examples of waste characterization and selected site characterization for Criteria Listing are shown in Tables 1 and 2, respectively. A summary assessment of Criteria Listing is given in Table 3.

TABLE 1

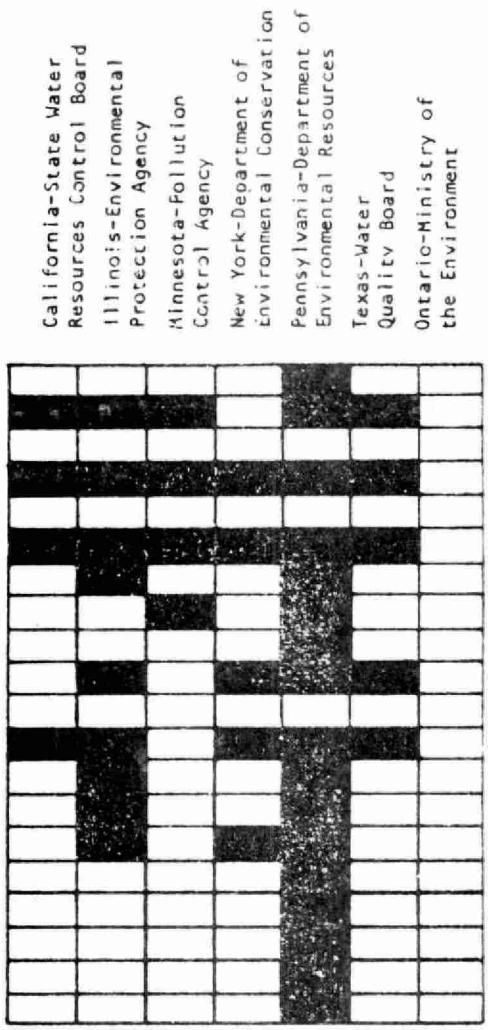
WASTE CHARACTERIZATION - CRITERIA LISTING*

Type:	Industrial
	SIC
	Plant name/location
	Waste stream
	Municipal - Specify waste/source
	Other - Specify waste/source
Amount:	Volume or weight
	Rate of generation
Physical:	Solid
	Liquid
	Sludge
Chemical:	pH
	Toxicity
	Major constituents
	Minor constituents
Biological:	Degradability
	Organic content

(* Compiled by Weston)

TABLE 2

-SITE CHARACTERIZATION-
SELECTED CRITERIA LISTING



GEOLOGY

- Backhoe Pits
- Borings
- Description of Geologic Profile
- Consolidated Deposits
  - Bedrock Type(s)
  - Formation Name
  - Outcrop
  - Degree of Weathering
- Depth to Bedrock
  - Unconsolidated Deposits
  - Type(s)
  - Formation Name
  - Texture
- Structure
  - Fold Axis
  - Bedding Planes
  - Joint Planes
  - Fault Planes
- Fracture Traces

HYDROLOGY

- Surface Water
  - Distance to Nearest Body
  - Type
  - Quality
- Ground Water
  - Depth to Water Table
    - Maximum
    - Minimum
    - Location and Date Measured
    - Seasonal Fluctuations

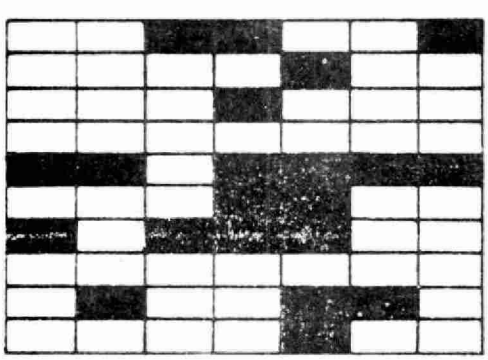


TABLE 3

SUMMARY ASSESSMENT OF CRITERIA LISTING

Pros

- Site-specific and quantitative data indentified.
- Comprehensive site description.
- Presently used by regulatory agencies
- Moderate cost/expertise requirements.
- Applies to hazardous and non-hazardous wastes

Cons

- No quantification of pollution potential.
- Potential high costs.
- Reliability largely dependent on the expertise of agency review personnel.

Criteria Ranking. The Criteria Ranking approach is based on measurements or estimates of waste and site parameters which are arbitrarily weighted based on their potential impact on the environment. Approaches have been developed which rate or rank wastes and landfill sites individually in order to allow a quantitative numerical comparison of various wastes and sites to one another. Those ranking approaches developed to date were intended to serve as a first step in waste and site evaluation. To date, however, neither approach has been applied to the prediction process for a new site.

A Numerical Rating System has been developed by LeGrand and Brown (1977) for a standardized approach for evaluation of groundwater

contamination potential from waste disposal sources and other contamination sites with land disposal. The system evaluates four key geologic and hydrogeologic characteristics of the site and assigns a numerical value ranging from 0, indicating extremely poor conditions or a high contamination potential, to a 9 (5 in one case), indicating good conditions or a low contamination potential. The Numerical Rating System for a given site consists of a sequence of numbers and letters to provide a general overall rating of the site indicating its specific weak and strong characteristics. The system is designed to provide a quick first round assessment of site suitability, but is not intended to be adequate or substitute for the more advanced or detailed study which may be required for certain critical contamination potential situations. Step 9, Completion of the Site Numerical Rating, is shown on Table 4.

Another Criteria Ranking approach was developed by Pavoni, Haggerty and Lee in 1971-72, entitled Environmental Impact Evaluation of Hazardous Waste Disposal in Land. Five waste ranking formulae and ten site ranking formulae were developed to assign weighted values and to assess potential site suitability by comparison with each other. A full description of each of these Criteria Ranking approaches is given in Section V.

A summary assessment of the Criteria Ranking approach is given in Table 5.

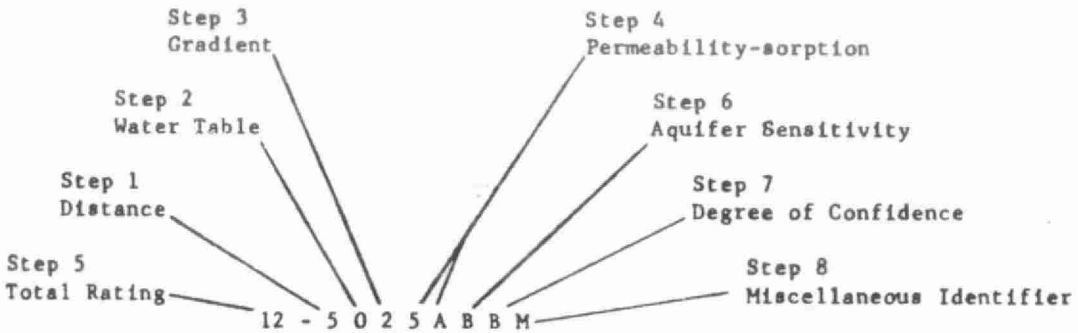
TABLE 4

COMPLETION OF NUMERICAL RATING
(from LeGrand and Brown, 1977)

STEP 9

Completion of site numerical rating

The total point value determined in Step 5 is recorded and then followed in sequence by the individual point values for the four key hydrogeologic factors: distance, depth to water table, water-table gradient, and permeability-sorption. This is followed, in turn, by the special site identifier suffixes: aquifer sensitivity, degree of confidence, and miscellaneous identifiers. An example of a site rating with brief explanations and interpretations is shown below. Full explanations of site ratings are in Sections 5.0 and 6.0.



Explanation of sequence of digits and letters

12 - Total point value as shown in Step 5
5 - The first digit is rating for ground distance - Step 1
0 - The second digit is rating for depth to water table - Step 2
2 - The third digit is rating for water-table gradient - Step 3
5 - The fourth digit is rating for permeability-sorption - Step 4
A - Represents a closely defined position (5A) in permeability-sorption scale - Step 4
B - Represents sensitivity of an aquifer to be contaminated - Step 6
B - Represents degree of confidence or reliability of overall rating - Step 7
M - Indicates special conditions (mounding of water table in this case) - Step 8

TABLE 5

SUMMARY ASSESSMENT OF CRITERIA RANKING

Pros

- Site-specific data identified.
- Quantitative data.
- Low to moderate cost/expertise involved.
- Quantitative predictive tool.

Cons

- Confidence of assigned values.
- Lack of testing and calibration.
- Not presently used by regulatory agencies.

Matrix. The use of a Matrix as a prediction technique in waste disposal siting is dependent upon the formulation of relationships between two major sets of interrelated variables (e.g., waste characteristics and soil characteristics). A Matrix approach of this type has been identified in this study as given in the Development of a Soil-Waste Interaction Matrix by C.R. Phillips.

It should be noted that this soil-waste interaction Matrix procedure does not entail the development of a "new" procedure, but rather basically combines soil and waste ranking systems that had previously been developed with little, if any, revision by LeGrand (1964 site ranking) and by Pavoni, Hagerty, and Lee (waste ranking).

An example of the waste-ranking parameters and calculations for weighted value assignments is shown in Table 6. A waste/site dependent matrix with values for all of the parameters considered is shown in Figure 3. A summary assessment of the Matrix approach is given in Table 7.

TABLE 6

WASTE PARAMETER FOR INPUT TO MATRIX

Factor Summary

WASTE

		Range
(1)	Effects Group	
	1. Human Toxicity, Ht	0-10
	$Ht = \frac{10}{3} Sr$	
	2. Groundwater Toxicity, Gt	0-10
	$Gt = \frac{10}{7} (4 - \log_{10} Cc)$	
	but for $Cc > 10^4$ mg/l, $Gt = 0$	
	and for $Cc < 10^{-3}$ mg/l, $Gt = 10$	
	3. Disease Transmission Potential, NDp	0-10
	$NDp = \Sigma$ (contribution of subgroup A, B and C)	
(2)	Behavioral Group	
	(i) Behavioral Subgroup	
	4. Chemical Persistence, Cp	1-5
	$Cp = 5 \exp(-kt)$	
	but if $Cp < 1$, $Cp = 1$	
	where $C_6/C_1 = \exp(-kt)$	
	5. Biological Persistence, Bp	1-4
	$Bp = 4 (1 - \frac{BOD}{TOD})$	

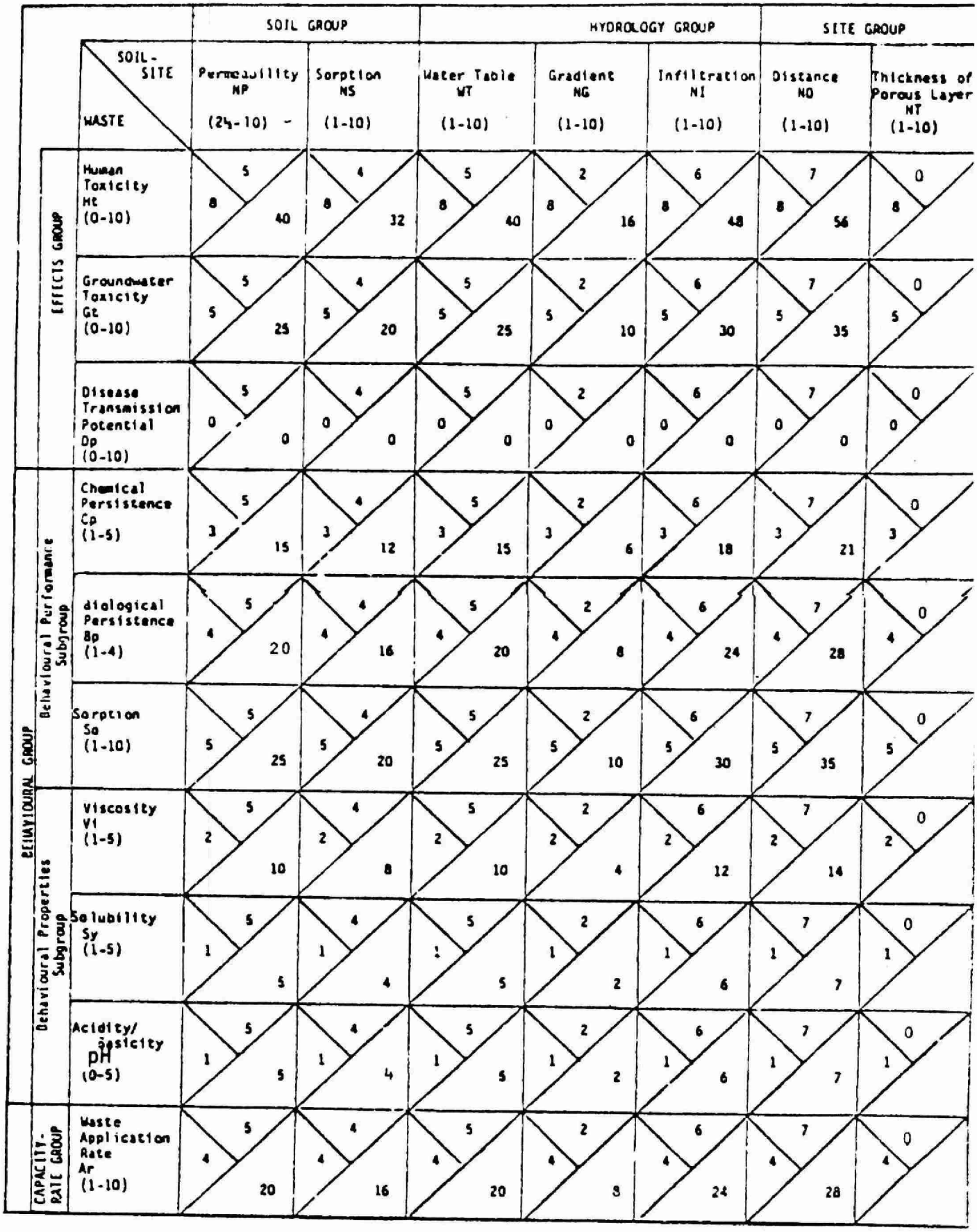


FIGURE 3 EXAMPLE OF SITE DEPENDENT MATRIX
(C.R. PHILLIPS)

TABLE 7

SUMMARY ASSESSMENT OF THE MATRIX

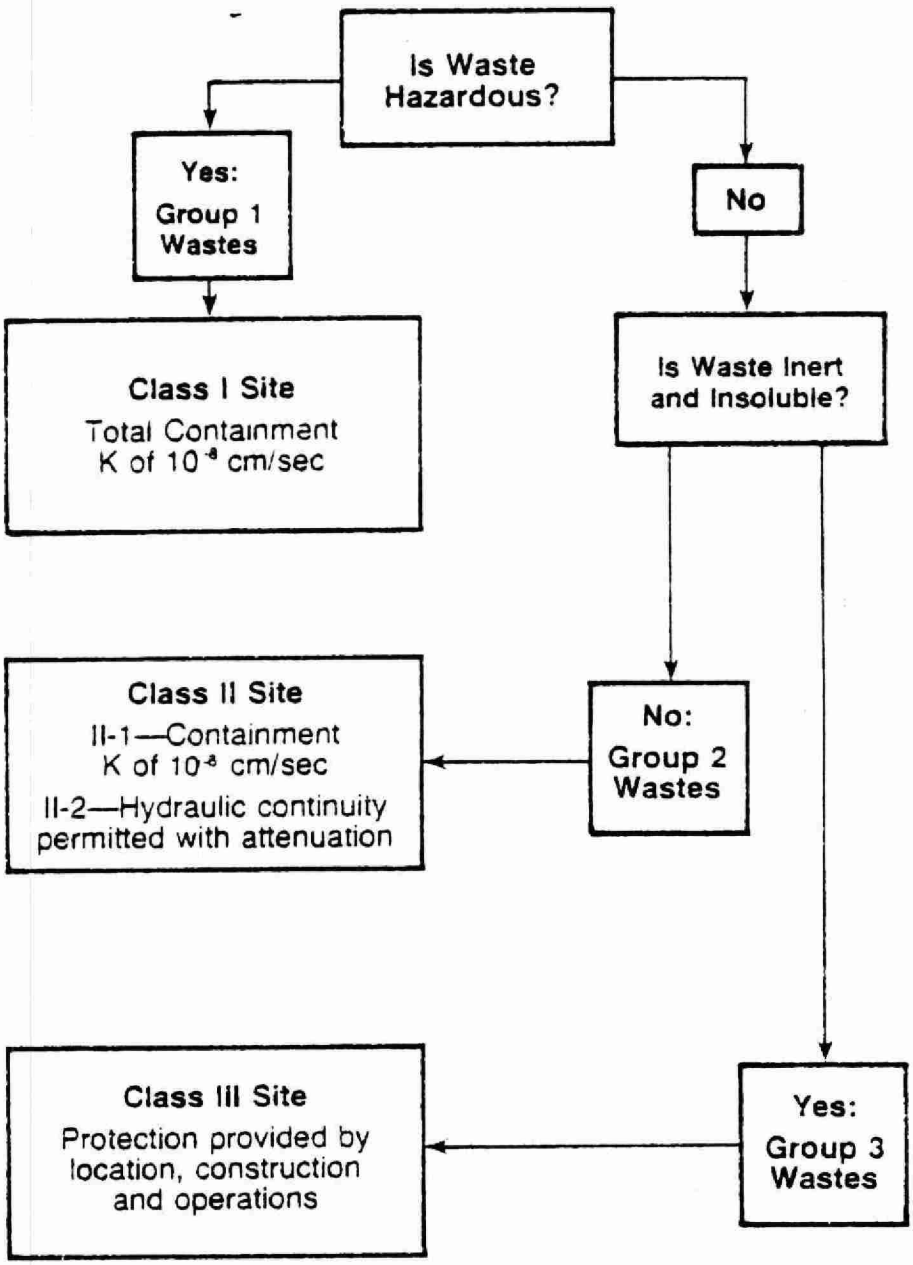
Pros

- Quantitative predictive tool.
- Identification of soil/waste parameters.
- Assessment of pollution potential.
- Low-moderate operating cost.

Cons

- Confidence of assigned values.
- Lack of testing, calibration and field verification.
- Not presently used by regulatory agencies.
- Difficulty of laboratory and field quantification of parameters.
- Specialized skills usually required.

Classification System (Decision Tree). The Decision Tree approach is a logical step-by-step process for assessment of the pollution potential in the site selection process. The Decision Tree approach begins with the most important question followed by a hierarchy of questions of decreasing criticality. In this manner, a "no" answer to an early important question can eliminate the site from further consideration and, from a practical standpoint, the expenditure of unnecessary money for additional site investigation. A "no" answer may also indicate that an alternative type of waste disposal site or disposal method should be utilized. This approach is in effect that developed by the California State Water Resources Control Board in their waste/site Classification System (as shown in Figure 4). A summary assessment of the Classification System is given in Table 8.



Based on "Disposal Site Design and Operation Information." California State Waste Resources Control Board

FIGURE 4 CLASSIFICATION SYSTEM (DECISION TREE)

The basic approach taken in the California Classification System is a determination of the degree to which waste is hazardous and its assignment to one of three main classes of disposal sites. For each site class, varying degrees of protection are provided for surface and groundwater, with the system permeability being defined as the single most important and controlling site parameter. The wastes are classified as Group 1, 2 or 3, and the sites are classified as Class I, II, and III as shown in Table 9.

TABLE 8

SUMMARY ASSESSMENT OF CLASSIFICATION SYSTEM
(DECISION TREE)

Pros

- Site/waste comprehensive.
- Specifically addresses hazardous wastes.
- Presently used by regulatory agencies.
- Tested and verified.
- Low cost/expertise requirements.

Cons

- Insufficient data requirements.
- Local and regional availability of low permeability deposits.
- Little quantification of pollution potential.
- Possibly too conservative.

Simulation Models. Predicting the potential for groundwater pollution from waste disposal operations is complex because of the interactive and simultaneous processes that occur in a soil-water system. However, models can serve as a tool to simulate the performance of a certain disposal site. Models can be classified as: (1) descriptive models; (2) physical models; (3) analog models; and (4) mathematical models.

TABLE 9

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD
DISPOSAL SITE DESIGN REQUIREMENTS

Site Type	Site Classification	Waste Classification	Permeability cm/sec	Soils	% Passing a No. 200 Sieve	Liquid Limit	Plasticity Index
Class I	Complete protection is provided for all time for the quality of ground and surface water. Geological conditions are naturally capable of preventing vertical and lateral hydraulic continuity between liquids and gases from the waste in the site and usable surface and ground waters. The disposal area can be modified to prevent lateral continuity. Underlain by usable ground water only under exceptional circumstances.	Group 1 Consisting of or containing toxic substances and substances which could significantly impair the quality of usable waters. Also accepts Group 2 and 3 wastes.	$\leq 1 \times 10^{-8}$	CL, CH or OH	Not less than 30	Not less than 30	Not less than 30
Class II	Protection is provided to water quality from Group 2 and Group 3 wastes.	Group 2 Consisting of or containing chemically or biologically decomposable material which does not include toxic substances or those capable of significantly impairing the quality of usable water. Also accepts Group 3 Wastes.					
II-1	Overlying usable ground water and geologic conditions are either naturally capable of preventing lateral and vertical hydraulic continuity or site has been modified to achieve such capability.		$\leq 1 \times 10^{-6}$	CL, CH or OH	Not less than 30	Not less than 30	Not less than 30
II-2	Having vertical and lateral hydraulic continuity with usable ground water but geological and hydraulic features and other factors assure protection of water quality.		Not specified	Not specified	Not specified	Not specified	Not specified
Class III	Protection is provided from Group 3 wastes by location, construction and operation which prevent erosion of deposited material.	Group 3 Consist entirely of non-water soluble, non-decomposable inert solids.	-	-	-	-	-

In addition to the above groupings, models could be classified as: (1) empirical versus conceptual models; (2) stochastic versus deterministic models; (3) static versus dynamic models; and (4) spatial dimensionability (one, two or three dimensions considered). Table 10 lists a few example models and their classification into various groupings.

Of the different models discussed above, conceptual-mathematical models appear to be the most promising, but these are also the most complex for evaluating potential groundwater contamination for a given site. These models are generally based upon a set of equations which describe the relationships between different input and output variables and system parameters. These equations are derived using the principles of conservation of mass, energy and momentum, and constitutive relationships which define certain systems. Several models of this type are currently available.

Equations 6 and 7 (in Section V of this report) are examples of constituent-transport and water-flow equations, respectively. Mathematical solutions of Equations 6 and 7, or simplified versions of them, may be generated in several ways: (1) analytical methods, and (2) numerical methods which include finite differences, finite element, and method of characteristics.

Survey of Existing Mathematical Models. The literature contains hundreds of solutions of different variations of mathematical models. Section V of this report includes a detailed discussion of these solutions, a wide variety of models, and identifies methods for their solution and application.

Several problems related to model use are identified in Section V; however, they can be considered a promising tool for predicting groundwater contamination potential. Further research and investigations are needed prior to full implementation of such tools. Table 11 summarizes model development by type.

TABLE 10

EXAMPLE MODELS AND THEIR CLASSIFICATION INTO DIFFERENT GROUPINGS

Model Definition	TYPE OF MODEL: Descriptive (D) Physical (P) Mathematical (M)	Conceptual (C) Empirical (E)	Stochastic (S) Deterministic (De)	Static (St) Dynamic (Dy)	Spatial Dimension (1, 2, 3)
On-site inspection and decision using engineering judgment.	D	E	De	Dy	3
The Drexel University experimental landfill (field site only)	P	E	De	Dy	3
Batch equilibrium study to determine adsorption; shaker test; solid waste evaluation leachate test (subsystem models)	M	E	De	St	0
Column study to determine adsorption and/or migration of certain chemicals in given soil; thin-layer chromatography (subsystem models)	M	E	De	Dy	1
Criteria listing; classification system of the California State Water Control Board; matrix method.	D and M (Matrix)	E	De	St	-
One-dimensional unsaturated transport model of Bresler (1973) (subsystem model)	M	C	De	Dy	1
Two-dimensional saturated-unsaturated transport model of Duguid and Reeves (1976)	M	C	De	Dy	2
Model for groundwater flow and mass transport under uncertainty of Tang and Pinder (1977).	M	C	S	Dy	2

TABLE 11

SUMMARY OF MODEL DEVELOPMENT BY TYPE

ACTIVITY	STATE OF DEVELOPMENT			
	FLUID FLOW	MASS TRANSPORT		
		SINGLE-ION TRANSPORT		MULTI-ION TRANSPORT (+EXCHANGE)
		NO ADSORPTION NO DECAY	WITH ADSORPTION WITH DECAY	
1. Mathematical formulation of any model	0	0	D3	D3 - ?
2. Numerical solution of any model	0	0	D3	D3 - ?
3. Field calibration and testing:				
saturated/unsaturated transport	0	D3	D6	D6 - ?
saturated-only transport	0	0	D3	D6 - ?
unsaturated-only transport	0	0	D3	D6 - ?
4. Field verification:				
saturated/unsaturated transport	D3	D3	D6	D10 -?
saturated-only transport	0	D3	D3	D6 - ?
unsaturated-only transport	0	0	D3	D6 - ?
5. Methodology for laboratory and field quantification of major parameters[1] (any model)	0	D3	D3	D6 - ?
6. Methodology for quantification of leachate quality	NA	NA	0	0
7. Standard procedures for field testing, calibration and verification (any model)	D3	D3	D6	D10 -?
8. Ready for use as a decision procedure				
saturated/unsaturated transport	NA	D3	D6	D10-?
saturated-only transport[2]	NA	D3	D6	D10-?
unsaturated-only transport[2]	NA	D3	D3	D6 -?

0 = operational;
D3 = under development, likely to be operational within three years;
D6 = under development, likely to be operational within six years;
D10= under development, likely to be operational within ten years;
? = under development, not likely to be operational within ten years;
NA = not applicable

1) adsorption/exchange constants, dispersion coefficients, soil hydraulic properties, etc
2) if the indicated transport model is suitable for application at given site.

Soil-Leachate Column Studies. Soil-column studies have been used to simulate natural field conditions and to quantify the potential for a given soil to attenuate specific constituents. Most laboratory experiments are conducted using water-saturated soil or clay systems. Unsaturated soil-water conditions are difficult to control, and the soil water flow rates are extremely small for these cases. Soil-column studies are useful, but are frequently improperly interpreted. It is difficult to quantify the degree of attenuation based on presence or absence of leachate constituents in the column effluent. However, they remain a useful tool in determining hydraulic properties and dispersion coefficients for specific soil or clay materials.

Batch or Shaker Tests. Several types of experiments can be used for measuring adsorption characteristics, but the most widely used is the "batch" or "shaker" method. This procedure consists of combining a known volume of waste leachate of a predetermined composition with a given mass of air dry soil. The mixture is shaken until equilibrium is attained. Adsorption coefficients can be determined from the distribution of the constituents between the adsorbed and water phases. Batch or shaker adsorption tests can be useful in evaluating constituent mobility, but it may be misleading if appreciable complexing of constituents occurs during the contact period. However, if properly conducted, these tests can be used to provide necessary parameters for mathematical models.

Thin-Layer Chromatography. Soil thin layer chromatography (soil TLC) is analogous to conventional TLC, with soil substituted for the paper or solid absorbent phase. This procedure appears to correlate well with mobility "trends" observed in laboratory-column studies and in batch-adsorption experiments. The procedure consists of coating a glass plate with soil slurry (500-750 μ) followed by drying. The "mobility" of constituents is then measured in relationship to migration of the water front as shown in Figure 5.

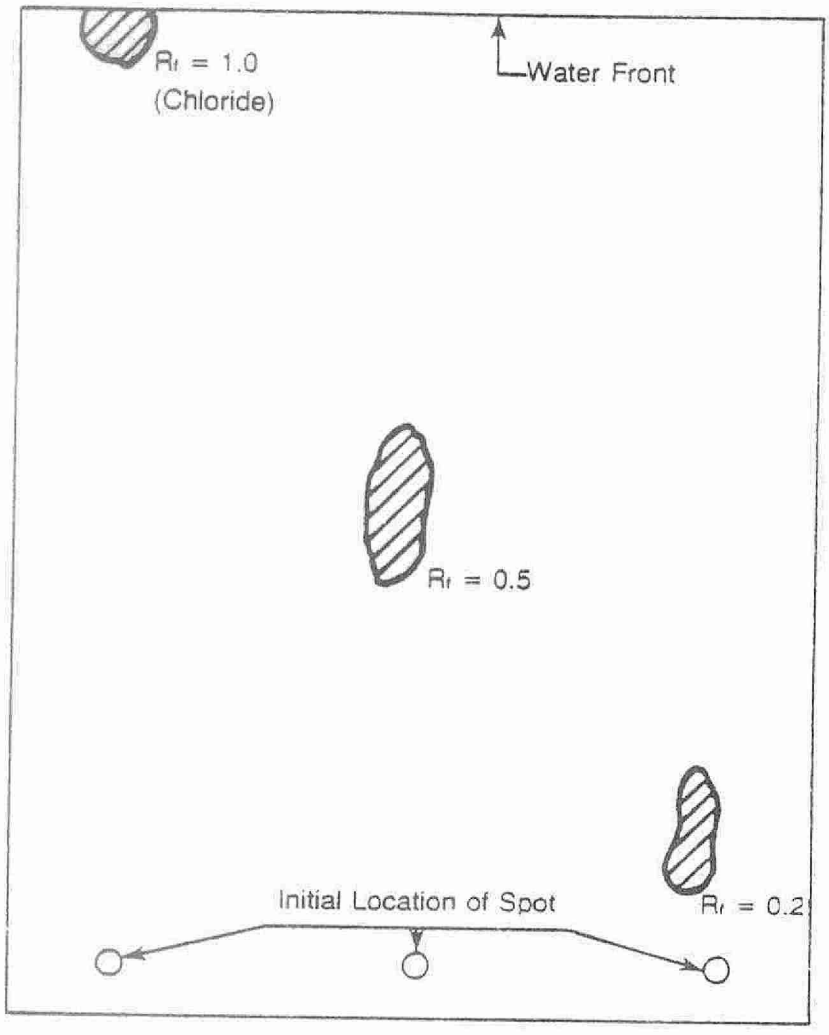


FIGURE 5 THIN-LAYER CHROMATOGRAPHY

The shaded areas represent three different constituent locations after the water front has migrated to 10-cm height above the initial location of each spot. The shaded area with an R_f equal to one represents a non-adsorbed constituent such as chloride with the least mobile constituent in the illustration having a R_f of 0.2.

Dilution Model. This type of model defines the potential for groundwater contamination strictly on the basis of: leachate dilution in groundwater, dilution in down-gradient well discharge, and travel times for leachate migration both to down-gradient wells and streams.

On-Going Research. Several researchers, research institutions federal agencies, and universities have developed, and are currently in the process of developing, mathematical models for the prediction of contaminant migration in subsurface environments. These include: the U.S. Geologic Survey; Battelle Pacific Northwest Laboratories; Oak Ridge National Laboratory; Colorado State University; Cornell University; Drexel University; Ecole de Mines, Fontainbleu, France; Institue de Mecanique des Fluides de Starbourg, Strass, France; New Mexico State University; Princeton University, the University of California, Davis; the University of Florida; the University of Cottingen, Germany; the University of New Mexico; Oregon State University of Oregon; the University of Waterloo; Utah State University; Technion - Israel; Institute of Technology and Intera/Intercomp Resources Development and Engineering, Inc.

Assessment. Models to be used as a decision procedure, whether they be mathematical or non-mathematical, should: (1) be rational; (2) represent the physical system; (3) be easy to understand; and (4) be economical to run. Modeling has the following advantages:

- Provide a quantitative prediction.
- Predict contamination potential before the fact.
- Identify soil/waste parameters.

- Perform multiple site/waste analysis.
- Can be versatile as a tool for ranking the site, for optimizing monetary design, and for defining waste management requirements.
- Can be a research tool.

Use of models as a decision procedure has the following limitations and disadvantages:

- Lack of testing and verification.
- Difficulty of quantifying input parameters.
- Complexity and requirements for a wide variety of expertise.
- Unknown accuracy and precision parameters and outputs.
- Unavailability of ready-to-use packaged models.

A summary assessment of models is given in Table 12.

TABLE 12

SUMMARY ASSESSMENT OF MODELS

Pros

- Quantitative - predictive tool.
- Identification of soil/waste parameters.
- Assessment of pollution potential.
- Versatility.
- Research tool.

Cons

- Insufficient understanding of some processes.
- Insufficient testing and calibration.
- Lack of field verification.
- Difficulty of laboratory and field quantification of parameters.
- Requires specialized skills and equipment.
- High operating cost.

Regulatory Agency Practices

Permit Procedures Utilized. Nine state regulatory agencies in six states and regulatory agencies in four foreign countries were contacted for an assessment of their waste-permitting procedures. Those agencies contacted are shown in Table 13. Also shown are selected factors in these programs with respect to: the permit procedure utilized for waste disposal siting; the status of regulations pertaining to both municipal and hazardous waste regulations; the mode of disposal required, i.e., containment or attenuation; the containment permeability required; and estimates of applicant costs, agency processing time in months, and agency review time by personnel type in hours.

The permit procedures utilized by each of those regulatory agencies contacted are the Criteria Listing or Classification System. The Classification System is used by regulatory agencies in California (see Table 8), Illinois, Texas, and the United Kingdom. The Criteria Listing approach is utilized by the other regulatory agencies contacted in Minnesota, New York, Pennsylvania, Ontario, Canada, The Netherlands and West Germany.

It is noteworthy that the same basic rationale and permit procedures utilized by the domestic regulatory agencies contacted are also utilized by the foreign regulatory agencies in Ontario, Canada and Western Europe for the permitting of waste disposal operations. As stated above, either the Criteria Listing or Classification System approach is utilized by the foreign regulatory agencies. In addition, a major consideration of waste disposal permitting relates to the attenuation or containment of waste leachate. Containment of both municipal and hazardous wastes is required in West Germany. Municipal waste disposal and the co-disposal of industrial waste that may sometimes be hazardous municipal waste is, on the other hand, permitted with reliance on attenuation of waste leachates produced in Ontario, Canada, The Netherlands, and the United Kingdom.

TABLE 13

SELECTED FACTORS IN THE ASSESSMENT OF REGULATORY AGENCY PERMIT PRACTICES

Regulatory Agency[1]	Permit Procedure	Status of Regulations[2]	Regulatory Authority[3]	Mode of Disposal[4]	Containment Permeability (cm/sec)	Applicant Costs for Permit Aquisition[5] Technical	Hearing	Time Process Permits - Range and Average (months)	Regulatory Staff Processing Time (hours) Technical	Admin.
Domestic										
California Regional Water Quality Control Board[1]	Classification System	Revised December 1976	Hazardous Wastes	Containment	HW: $\leq 1 \times 10^{-8}$ MW: $\leq 1 \times 10^{-6}$	$250,000 to	$100,000	8-18; 12	80	12
California State Solid Waste Management Board	Classification System	Revised 1976	Municipal Wastes	Containment	MW: $\leq 1 \times 10^{-8}$ MW: $\leq 1 \times 10^{-6}$	800,000		8-18, 12	NA[6]	NA
California Department of Health	Classification System	Feb. 1975 Being Revised	Hazardous Wastes	Containment	MW: $\leq 1 \times 10^{-8}$ MW $\leq 1 \times 10^{-6}$			8-18, 12	NA	NA
Illinois Environmental Protection Agency	Classification System	Revised-Pending Approval mid-1978	Both	Containment	HW: I-$\leq 1 \times 10^{-8}$ II-$\leq 5 \times 10^{-8}$ MW: $\leq 1 \times 10^{-7}$	25,000 to 50,000		1-3; 1½	80	16
Minnesota Pollution Control Agency	Criteria Listing	Being Provided (Draft Reg. June 1977)	Both	Containment	HW: $\leq 1 \times 10^{-7}$	25,000 to 200,000	up to 50,000	6-12; 8	320	80
New York Department of Environmental Conservation	Criteria Listing	Revised August 1977	Both separate sections	Both as specified	HW: $\leq 1 \times 10^{-7}$			3-6; 3	35	5
Pennsylvania Department of Environmental Resources	Criteria Listing	Revised June 1977	Both	Both as specified	HW: $\leq 1 \times 10^{-7}$ MW: $\leq 1 \times 10^{-7}$, if specified	15,000+	up to 60,000	6-18, 12	280	20
Texas Department of Health Resources	Classification System	Revised April 1977	Municipal Wastes	Containment	HW: $\leq 1 \times 10^{-7}$ MW: $\leq 1 \times 10^{-7}$			2½-16; 7	83	17
Texas Water Quality Board[1]	Classification System	Revised-Pending Approval Late 1977	Hazardous Wastes	Containment	HW: $\leq 1 \times 10^{-7}$ MW: $\leq 1 \times 10^{-7}$	50,000 to 200,000	5,000 to 10,000	6-12; 8	240	112
Foreign										
Canada - Ontario Ministry of the Environment	Criteria Listing	SW-Revised Feb. 1976 HW-Being Drafted	Both separate sections	Attenuation	not specified	50,000	20,000	8-36; 24	NA	NA
Netherlands - SVA	Criteria Listing	Being Revised	Both	Attenuation	not specified			NA		
United Kingdom - Greater London Council	Classification System	Revised 1976	Both	Attenuation	not specified	up to $2.63 million total		2-9; 3	NA	NA
West Germany - Office of State of Bavaria for Environmental Protection	Criteria Listing	SW-Revised Sept. 1976 HW-Being Drafted	Both	Containment	HW: not specified MW: $\leq 1 \times 10^{-6}$	20,000 to 90,000		6-24; 12	NA	NA

[1] Indicates agency responsible for hazardous waste regulation.
[2] Includes both municipal (MW) and hazardous wastes (HW) unless specified.
[3] Municipal and/or hazardous wastes.
[4] Municipal wastes only, all hazardous wastes require containment unless otherwise specified.
[5] Costs given are gross estimates generally for off-site facilities.
[6] Information not available.

The basic decision procedure utilized by each of the regulatory agencies contacted is based upon: (1) an objective quantification of both waste and site characteristics; (2) the combined technical expertise of the permit review team; and (3) by comparison with empirical data generated from analagous waste disposal operations. In the final analysis, therefore, a subjective decision is made based upon utilization of objective data and analysis to the degree that the data will permit. It is universally agreed by both regulatory and non-regulatory experts that this final decision must of necessity be subjective since no alternative procedure presently exists or is anticipated to exist within the near future that could be relied upon for a final objective decision.

Modes of Disposal. From an assessment of these regulatory programs, it has become clear that three major modes of land disposal of wastes exist. The first mode of disposal places reliance on the containment of wastes and waste leachates produced to avoid adverse impacts on surface and groundwater quality. The second mode of deposition relies on the assimilation of waste leachates into the environment to an acceptable degree by the various mechanisms of attenuation. The third mode relies on neither containment nor attenuation, but on the site construction and aesthetics.

Accordingly, three major classes of waste disposal sites have been defined with three corresponding major groupings of wastes. This Classification System is best exemplified in the California Waste Regulatory Program. It does apply generally, however, to those Classification Systems developed elsewhere, such as Texas, Illinois, (pending) and the United Kingdom.

These Classification Systems may be most aptly summarized as follows:

Site Type	Mode of Disposal	Waste Type
Class I	Containment	Group 1 - Hazardous
Class II	Limited containment, with attenuation	Group 2 - Decomposable, non-hazardous
Class III	Few controls, no containment or attenuation	Group 3 - Inert, insoluble

It is nearly universally agreed that hazardous wastes should be deposited in a Class I type site. Co-disposal of certain "hazardous" wastes with municipal wastes, however, is permitted on a case-by-case basis in a non-contained (Class II) site by some regulatory agencies. In addition, it is recognized that certain hazardous wastes must undergo some form of pretreatment (such as neutralization, fixation, or complexing) prior to land disposal or some other form of disposal such as incineration.

Although municipal wastes to date have been considered by many to represent Group 2 wastes, the current trend by an increasing number of regulatory agencies is for municipal wastes to be disposed of in a containment site as well. The third type of waste (Group 3), by virtue of it being inert and insoluble, requires little control other than obvious site construction and aesthetic considerations.

The over-riding element of consideration becomes one of the degree of risk associated with adverse environmental and public health impacts. It has become equally clear that, with few exceptions, attenuation has limited application to the safe disposal of many hazardous wastes given the current state of the art of prediction capabilities and economics of land disposal. The element of risk is simply too high for attenuation to be considered, particularly in light of the "maximum site utilization" philosophy mandated by current economics. This may change as the ability to model solute movement is improved. The Group 3

wastes, on the other hand, do not require the use of pollution-prediction procedures since no polluting wastes or leachates are involved.

The Group 2 wastes, those that are decomposable but non-hazardous, therefore, become the prime area for concentrated application of pollution-prediction techniques that emphasize attenuation. Pollution prediction techniques are needed that will more specifically define those wastes that can be reliable and permanently assigned to Group 1 and Group 3 wastes. Concurrently, pollution-prediction techniques are needed which will permit the assignment of wastes to a Group 2, Class II classification to maximize the beneficial attenuation capabilities of the environment while minimizing waste disposal costs.

Recommended Development Plans

Several types of pollution prediction techniques have been identified in the course of this study; these are: Criteria Listing, Criteria Ranking, Matrix, Classification System, and Simulation Models. Among these techniques, it is recommended that the following be more fully developed to provide a "standard" technique for waste disposal siting: (1) Criteria Listing, (2) Classification System, and (3) Simulation Models. Each of these development plans will require the multi-disciplinary team approach utilizing earth sciences (soils and hydrogeology), engineering, environmental, and chemical personnel. The Simulation Models development plan will require applied mathematicians and computer technician personnel as well.

Criteria Listing. It has been determined that Criteria Listing is currently the most widely-accepted approach utilized by regulatory agencies. Objectives of development of this procedure include: (1) development of a Criteria Listing for waste/site characterization; and (2) describing the best state-of-the-art methodology to quantify each of the Criteria Listed.

- Development Tasks:

  1. Develop a comprehensive Criteria Listing for waste/site characterization, where reliance will be placed upon attenuation of leachates produced.

  2. Develop a similar list for waste/site characterization, where containment of leachate would be required.

  3. Develop a matrix for Tasks 1 and 2 which will specify those criteria necessary for waste/site characterization with respect to different types of disposal.

  4. Develop procedures based on the best state-of-the-art methodology to evaluate field and laboratory data relative to each of the criteria listed.

  5. Develop a methodology for utilization of attenuation and containment practices.

  6. Prepare a user's manual for applying the procedure for assessment of site suitability.

- Development Time:

  The development of a Criteria Listing for various types of waste disposal will require an estimated four man years of effort by a multi-disciplinary team within the next three years.

- Development Cost:

  Costs estimated at $200,000 for the above-described level of effort can be expected.

Classification System. Several state regulatory agencies have been identified which presently utilize a Classification System approach for waste disposal siting. However, there is a need for further development of this procedure to achieve the following: (1) more definitive waste characterization; (2) more uniform site characterization; and (3) more uniform waste management techniques. To achieve these objectives, the following tasks have been identified:

- Development Tasks:

    1. Identify and develop waste characterization techniques such as leaching tests, shaker tests, and thin-layer chromatography.

    2. Develop uniform criteria for site characterization, particularly for containment, permeability, and thickness of the containment media.

    3. Develop waste management requirements for different waste and site classes.

    4. Establish a waste management task force with a balanced representation of governmental, industrial, consulting, and academic personnel.

    5. Develop methodology for using the Classification System.

    6. Prepare a user's manual and update reports.

- Development Time:

  Due to the comprehensive nature of the Classification System approach, both short-term (within three years) and long-term (within ten years) development will be required. It is estimated that approximately five man-years of effort will be required for short-term development and a minimum of one man-years for each suceeding year of long-term development (seven additional years).

- Development Costs:

  Costs associated with these estimated times for development are estimated at $250,000 for the short term, and an additional $350,000 is estimated for the long term.

Simulation Models. Development of implementable simulation models will require a substantial effort both in the short term and the long term.

- Development Tasks:

  1. Establish and maintain a library of simulation models.

  2. Develop standardized sensitivity test procedures for numerical solutions of the models.

  3. Develop mathematical formulation and numerical solution of selected simulation models.

  4. Develop methodology for laboratory and field quantification of major model and simulation parameters.

  5. Develop methodology for quantification of waste leachate for specific soil and environmental conditions.

  6. Perform field testing, calibration, and verification of the models.

  7. Develop specific management models from detailed models.

  8. Obtain implementation assistance.

- Development Time and Costs

  The level of effort for the above development activities is significant and is estimated to be as high as 150 man-years. The bulk of the output from these development tasks is expected to be beyond the short term (greater than three years); however, certain outputs can be expected within the short term. The associated development costs are also significant and are estimated at approximately $6 million over the next ten years.

Conclusions and Recommendations

Conclusions. The overall objective of this study was to provide a state-of-the-art assessment of pollution prediction techniques for waste disposal siting. Emphasis was placed on current research and regulatory procedures. Furthermore, the emphasis was on techniques which lead to pollution prediction through assessment of attenuation of waste leachates especially those from hazardous constituents. The following conclusions can be drawn from this broad-scoped investigation.

1. A number of pollution prediction techniques, many of them interrelated, have been identified which constitute useful tools to objectively assess to varying degrees the suitability of specific waste and waste/site disposal situations. It must be emphasized, however, that a team of multidisciplinary professionals and not the pollution prediction technique itself provides the ultimate "yes or no" decision. In addition to technical considerations, economic, politcal and legal considerations must also be given.

2. Each waste disposal site is permitted by the regulatory agencies contacted on a case-by-case basis. Specific waste types are likewise permitted or rejected on a case-by-case basis from these disposal sites.

3. A definition of attenuation has been developed for this project as follows: "Any physical, chemical and/or biological reaction or transformation occurring in saturated and/or unsaturated zones that brings about a temporary or permanent decrease in the maximum concentration or total quantity of an applied chemical or biological constituent in a fixed time or distance traveled."

4. Several attenuation mechanisms play a role in reducing the potential for groundwater contamination: physical processes include - molecular diffusion, hydrodynamic dispersion, and dilution; chemical processes include - precipitation, oxidation/reduction, and ion exchange; and biological processes include biodegradation.

5. Soil/waste interactions and attenuation mechanisms are becoming better understood, but are in need of additional definition and quantification, particularly for the waste streams that commonly contain more than one type of waste.

6. Attenuation mechanisms are capable of renovation of leachates from many non-hazardous wastes and some hazardous wastes, provided that the application rate does not exceed the soil-attenuation capacity. Examples of the former include on-lot septic systems. Examples of the latter include land farming of petro-chemical wastes, sludges and pesticides.

7. Attenuation that is adequate to prevent pollution, for those wastes amenable to attenuation, may in large part be dependent upon assimilation by dilution into either groundwater or surface water.

8. Within the limits of current knowledge, many wastes categorized as hazardous are not amenable to attenuation in the soil profile and must rely upon containment in secured landfills or other methods of disposal.

9. It was established that three modes of disposal exist: (1) reliance on containment of waste and/or leachate; (2) discharge of leachate with reliance on varying degrees of attenuation; and (3) no reliance on either containment or attenuation. These modes generally correspond to disposal of hazardous waste, non-hazardous waste, and inert (innocuous) waste, respectively.

10. The following pollution prediction techniques have been identified in this state-of-the-art assessment: Criteria Listing, Criteria Ranking, Matrix, Classification System, Models and Laboratory Simulation.

11. The identified pollution prediction techniques and procedures that are currently available, or could be further developed, can be viewed as tools for gathering information for waste and site characterization to provide the decision-making professionals with a systematic and rational approach for site selection, evaluation, and permitting.

12. Criteria Listing is the most basic and commonly-used procedure by regulatory agencies for evaluating groundwater pollution potential from land-disposal sites.

13. The Criteria Ranking and Matrix approaches to pollution prediction are useful techniques for an evaluation of a site or waste/site disposal situation on a preliminary or "first-cut" basis, particularly for the comparison between several candidate sites. They do not,

however, provide the degree of detailed waste/site characterization necessary for final evaluation and approval of a permit.

14. The Classification System (Decision Tree) is being increasingly utilized as a tool for waste-disposal siting. This procedure is comprehensive for both waste type and site type, and could be developed into a "uniform" procedure for site selection and approval.

15. Numerous types of simulation models exist including descriptive, physical, analog, and mathematical models, with Conceptual-mathematical models appearing to be the most promising tool for simulation of groundwater contamination potential.

16. The potential for using mathematical models as a groundwater simulation tool depends on developing standardized methodology for leachate characterization, attenuation parameters, and numerical solutions; however, the degree of field testing, calibration, and verification of these models does not yet allow for wide application as uniform pollution prediction techniques.

17. The degree of sophistication and level of development of mathematical- and computer-simulation models far exceed those of parameter quantification, laboratory simulation, and field testing and verification.

18. Several laboratory procedures, such as Thin-Layer Chromatography and Shaker and Column tests, measure the potential for attenuation; however, their results could best be used as "subroutines" in a permit procedure since they do not account for all the interacting parameters that relate to the site-permitting process.

19. European and Canadian waste disposal permitting procedures including hazardous waste disposal closely parallel those permitting procedures identified in the United States. The two basic philosophies of containment versus attenuation apply in these countries as well but it is noteworthy that, with the exception of West Germany, reliance is placed on attenuation of leachates from municipal and many hazardous wastes to a much larger degree than in the United States.

Recommendations.

1. It is recommended that the following pollution prediction techniques be further developed for implementation to waste disposal siting: (1) Criteria Listing; (2) Classification System, and (3) Simulation Models.

2. The recommended development plan for the short-term (within 3 years) is the Criteria Listing approach. This plan includes: development of a uniform criteria listing, waste containment requirements, an assessment matrix, field- and laboratory-quantification methodology, data use requirements, and preparation of a user's manual.

3. A recommended development plan which encompasses both the short-term (within 3 years) and the long-term (within 10 years) is the Classification System. This plan includes: identifying waste characterization techniques, developing criteria for site characterization, and establishing a waste management task force.

4. The recommended development plan for the long-term, although short-term outputs can be expected, is that associated with simulation models.

5. Decisions for waste/site selection and permitting must be made by a team of professionals with expertise in earth science, environmental science and engineering, chemistry and chemical engineering, and, where appropriate, applied mathematics and computer science, using the techniques identified in this study as tools to reach decisions which are environmentally sound, consistent, rational, and defensible.

Facilities Using New Techniques To Treat Toxic Pollutants

by

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SCA Services, Inc.

Thank you very much for this opportunity to address the 25th Ontario Industrial Waste Conference. I would like to limit my remarks today to two subjects: first, the Earthline Corporation in Wilsonville, Illinois, and second, the Earthline Company in Newark, New Jersey. Both are facilities owned and operated by SCA Services, Inc. of Boston, Massachusetts.

Since some of you may not be familiar with SCA, let me take a moment to explain briefly who we are, and what we are involved in as a Company. SCA is the third largest Solid Waste Company in the United States. We operate Companies in 37 States, employee over 2,500 people, and will have revenues this year of 200 million dollars. The Corporation is divided into two basic divisions, a Solid Waste Division, which is primarily responsible for the pick up and disposal of municipal and industrial trash, and a Chemical Services Division, which is primarily responsible for the disposal of hazardous waste materials. The Chemical Services Division owns and operates five facilities in the United States. Those facilities are the Earthline Corporation in Wilsonville, Illinois, which is primarily a chemical landfill; Hartley and Hartley, Inc. in Kawkawlin, Michigan, which is basically an incinerator; Chem-Trol Pollution Services, Inc. in Model City, New York, which has the capability of chemical landfilling, aqueous treatment, resource recovery,

and other services; Earthline Company in Newark, New Jersey, which is our newest facility involved in the detoxification of bulk hazardous waste; and SCA Services of South Carolina, which we acquired in April of this year, which is a regional hazardous waste landfill. The combined revenues from waste disposal at these facilities in this year should exceed 20 million dollars.

One of our facilities which received a great deal of publicity last year was the Earthline Corporation in Wilsonville, Illinois, which was acquired by SCA in October 1976. Most of you have probably heard of this facility as a result of the incident which occured in the Spring of 1977 when PCB's were illegally dumped on a farm in Missouri. Because the PCB's were found in a nearby creek, the Federal EPA Emergency Unit was called in to clean up the site. The debris, dirt, and trash was drummed and sent to Wilsonville. It was the public attention to this, and a priest in the community, who became concerned about our handling potentially carcinogenic materials at this site, which led to the legal procedings, and injunction against the site and all the problems we have had since that time.

Prior to our purchasing the site, it was determined by Douglas Andrews, Director of the Hazardous Waste Division of the State of Illinois EPA and now owner of his own engineering firm, that a definite need existed for a hazardous waste site in Southern Illinois. He also was aware that in the Wilsonville area an abandoned coal mine was creating an environmental problem for the local community and waterway. The tremendous mine spoil pile at the abandoned site was leaching acidic water into the Town water supply and various tributaries. He also knew that the area had clay, which met the most stringent standards for a

chemical landfill. That is, has a permeability of greater than 10 to the minus 8 centimeters per second. Mr. Andrews, in conjunction with the owner of the site and developer, began to develop the site as a hazardous waste landfill. They made application to the State of Illinois in January of 1976 to develop the site, and began to implement a plan for monitoring wells, fencing, clean up, etc. Later in 1976 Mr. Andrews applied for an operational permit, and after the Illinois EPA had determined that the facility did meet all the requirements this permit was granted, and the site was able to begin receiving materials in October of 1976. Between Mr. Andrews, the developer, and SCA substantial sums of money were spent in developing the property and obtaining the permits for hazardous waste treatment and disposal. Our first concern was to eliminate the problem from the mine spoil or slag by covering it with clay. It is interesting to note that the State of Illinois had spent over $470,000 cleaning up a similar mine spoil within the State on a tract of land very near Wilsonville.

It is important that you understand that by granting an operational permit the Illinois EPA does not, itself, permit toxic materials to come into the site. In addition to the general operating permit, Earthline must obtain a specific permit for each material brought into the site. These permits are called supplemental permits, and they are good for a period of one year. They must specify the precise material being treated, the manner in which it will be handled, and the total composition of the material. We received a supplemental permit to handle this particular spill of PCB's from Missouri, and we had been handling PCB's prior to this incident on a very limited basis, again under supplemental permit.

The problems that occured were the result of the extensive publicity

associated with the spill plus it was a Missouri problem being handled in Illinois because there was no facility in Missouri capable of handling PCB waste. The citizens in the community were stimulated to take action by several local citizens and a priest who claimed that we were bringing in material, which would create a tremendous hazard to their health, their environment, and what have you. They filed an injunction to have the site closed almost immediately after we had begun receiving this waste. We had the injunction over-turned the same day. Shortly thereafter, events became as heated and well known both locally and nationally, that the Governor of Illinois declared a temporary 45 day moritorium on waste coming into Illinois. It was also an opportunity for many local, mostly unknown, politicians to receive a great deal of favorable publicity both in the newspapers and through the television media. It became apparent to us that the only solution to the problem was a full legal settlement via the courts. To date in defending the site SCA has spent over $400,000 in legal fees. The case has not yet been decided, although, it is in the hands of the judge, and a decision from the lower court should be forthcoming in the next several weeks.

During the beginning days of the problem, there were some violent times. The few people very much opposed to our bringing waste into the facility were able to stir up the entire community. Many many of the facts were totally distorted. The newspaper and television media were constantly on hand for the first several weeks of this problem, thus giving people an opportunity to bring any particular problem that existed in the community to light allegedly as a result of our being at the site. The newspaper reported anything that was said, such as, a lady complaining that her plants were no longer as greens as they used to be prior to our

being there, or water tasting funny, or animals in the Town not behaving the way they used to, children not feeling well, or a scum appearing on a swimming pool since we began to receive PCB's. It was apparent that the community was quite disturbed, and of course, the more people chatted amongst themselves the more upset they became. For example, they began hanging people in effigy, all of the flags on Main Street were hung upside down, nails were placed on the road at the entrance to our plant, and signs were errected "Wilsonville, the Dumping Ground of the Nation". It did not prohibit our bringing waste materials other than the PCB's into the site during these first few violent weeks. There were even incidents of rocks thrown at the trucks, and other types of problems. Some of the citizens even displayed weapons and threatened our people. We would go to court and receive relief through the courts to stop some of the more severe activity that occured, and try to bring reason to the situation. As it turned out, there was no way that we, operating our type of facility, could rationalize what we were doing with the local populas. It became obvious that the only solution was through the courts. We received the support of the Illinois EPA, and we had the Federal EPA testify on our behalf as a friend of the court. The Federal EPA, as a result of this action, conducted an extensive and thorough detailed study of the site and determined that it is one of the finest hazardous waste landfills in the United States, and one of the most acceptable facilities for the landfilling of PCB wastes. Our spill occured in the Spring when the weather was nice. We had the entire Summer for citizens to collect, stand around, and become involved. As time went on and it began to drag on in the courts, and no other incidents occured, and the newspapers and press lost interest in the case things

began to settle down in the community. As Winter drew near with the weather turning bad, the situation actually calmed down reflecting no incidents or problems at all during the Winter months. It is like the old adage "Time heals all wounds". That seemed to be the case at Wilsonville.

It is unfortunate that this situation occured. From our point of view it has cost us a substantial sum of money which will never be recouped, however, has been necessary in order for us to establish that the facility is acceptable, necessary, safely run, well operated, and can be a benefit to the community. In the year that has followed the incident, we have successfully completed covering most of the slag pile reducing significantly the acid run off from this. We have undertaken a major beautification program of the site so that from the community it is not obvious at all that there is a chemical landfill operation being conducted. We have voluntarily restricted the method of shipment of materials into the community and into the site so as not to create additional problems.

Not necessarily as a result of our problem at Wilsonville, but more through the nature of our business, we have seen in the last year other sites operated by different companies come under similar pressure from the local communities to have the sites closed. This, of course, has put a great deal of strain on the various State agencies and Federal EPA, who recognize the need for these sites and their benefit to industry. We do not have answers to the problem of how to avoid these types of incidents in the future. It is almost as though you have to say to yourself if you are going to construct and operate a hazardous waste facility that you must expect public reaction to be negative, and be prepared to spend the necessary

funds and time to resolve the matter legally.

Prior to our opening the Wilsonviile site I should note that the local citizens were made aware of our intentions. Letters and full descriptions of what we were planning to do were sent to every leading citizen, politician, and what have you within the County, State, and Town. They were very much aware of what the facility was going to do, and it was not until the PCB incident and the few people becoming extremely concerned that the situation became unmanagable.

Until several weeks ago when a very minor spill of a non-hazardous material occured at the entrance to our facility (the spill by the way was no more than a pint of material) we have had no particular problems with the local community since the Fall of 1977. This particular spill I just mentioned resulted in a minor confrontation with citizens in the village and lasted about a day, and that has since quieted down. We are presently operating the facility to service customers in a many state area and have had no problems with the Illinois EPA in obtaining supplemental permits for waste materials which we have determined to be suitable for landfilling at the site.

I would now like to direct my comments to our newest waste treatment facility in Newark, New Jersey, the Earthline Company.

Although the names are similar they are separate Divisions of SCA, and are not related to each other. The Chemical Waste Services Division of SCA is a growing division. We are constantly looking for new facilities and new technology. With this in mind in the Fall of 1977 we learned of a plant in Newark, the old International Minerals and Chemical Company, which was for sale. We looked at the site to develop a new and unique hazardous waste treatment facility. The facility is the first of its kind in the world

to utilize totally new technology for the detoxification of hazardous waste. It compliments very well the broad range of disposal capabilities with SCA. Once we had reached an agreement with IMC and had finalized all the terms we began working with the State of New Jersey to secure the necessary permits, etc. to begin operation of this facility. We anticipate opening the facility for receipt of waste products in early July of this year. We will bring the plant on stream over the course of the next six to eight months. For the past six months we have invested a substantial sum of money revamping the plant, tearing out useless equipment, adding new equipment, repiping, and totally revising the facility to handle bulk, liquid hazardous waste.

Earthline's plant processes are based on chemical modification of functional groups. In general, the deactivation of reactive functional groups, such as, volatile acids is accomplished by converting one chemical into another chemical that is less reactive or non-reactive. Incoming waste streams will be classified according to five major functional groups based on processing operations. The first is organic reclamation of contaminated aqueous waste, the second is acid recovery, the third is fuel reclamation and reformation, the fourth is acid base neutralization, and the fifth is hazardous waste detoxification. We will comense operation using the hazardous waste detoxification section of the plant and fuel reclamation and formulations sections first. The other areas will be phased in by early 1979. The plant has the capability of initially handling between 100 and 200 thousand gallons per day of liquid waste, and when fully on stream should be capable of handling up to a half a million gallons a day of hazardous waste material. It is not designed to handle solid materials, and we would perfer on a limited basis to handle as few drums as possible.

The initial phases of operation will employee in some cases totally new technology to our industry, which has been developed by Dr. Sam Lee, Director of Research for the SCA Chemical Waste Services Division. Let us take an example of a contaminated aqueous waste stream. The material will be brought in, treated chemically and catalitically such that the toxic components will be changed in chemical composition to a non-toxic material. In some cases many of the components will be precipitated. The remaining aqueous phase after going through close monitoring will be further treated and discharged to the Passaic Valley Sewer Authority.

You may be wondering what type of equipment we are going to have at this facility in order to perform detoxification and recovery. This plant was formerly used to manufacture specialty chemicals, and has extensive glass lined reactors, glass lined piping, nickel tanks, distillation equipment, fractional columns, complete warehousing, and office space.

The requirements and restrictions placed on us by the New Jersey EPA are stricter than for any waste disposal facility in the United States. We have complete monitoring of our discharge to the Passaic Valley Sewer System. The building with the monitoring equipment has a key available only to the New Jersey authorities. All storm drains within the plant confine have to be blocked so that we could have no spill or illegal discharge into the storm drain system, and this is monitored. The existing tank farm, which was on the site, had to be completely removed, and 56 pilings driven under the site of the tank farm and a new concrete pad put in place because of the possibility of subsidance with the distribution of weight varing significantly in the area. The incoming truck receiving station is completely diked to contain the equivalent of a spill of an entire truck load of material. The solvent recovery system has numerous flame safety arrest devices to prevent

any possible type of fire. This was a result of the Rollins explosion. We have had to obtain over 20 separate permits in order to operate, discharge, etc.

The facility is primarily designed to handle large volumes of highly toxic waste streams. Materials which here to for have only been able to be handled by the manufacturer themselves at great costs or through methods of disposal not acceptable under proposed RCRA regulations. We expect to service customers from a broad geographic area of the United States and Canada, with the capability of receiving material via truck and rail.

We anticipate having products for sale, recovered from waste products. We will also have one of the largest waste fuel programs in the Country eminating from this site. The waste fuels will be made up of organics recovered and stripped from many of the waste streams, which we anticipate bringing into the facility. We have developed the technology and plan to recover concentrated sulfuric acid from nitration grade acids contaminated from various organics. We are working on new technology for recovering specific organic components from certain large volume waste streams that here to for have been destroyed by incineration or some other form of treatment.

Many of the processes for which we treat the waste will cause us to generate a sludge. This sludge will be of a nature that it could not be sent to a normal sanitary landfill and we will, therefore, dispose of these sludges at other SCA facilities that operate chemical landfills, such as, Chem-Trol or Earthline, Wilsonville, Illinois or our newest landfill in Pinewood, South Carolina. Although these sludges will be chemical sludges they will have been, for the most part, converted to non-toxic chemicals.

Detoxification is a relatively new concept in the field of waste disposal. We have recognized the need for this type of facility for a long time, and

we are fortunate in finding this particular plant to use to provide this service to industry. Our investment will be several million dollars, but we firmly believe that with the new RCRA requirements and the demands placed on industry for proper disposal that we will have a facility that can service the needs of many people, who at this point in time, have no other alternative for disposal.

Thank you.

THE YEAR OF NEW RESPECT FOR WASTE MANAGEMENT

by
Thomas W. Drew,
President, D & D Group

SINCE LIFE BEGAN WE RESIDENTS HAVE NOT BEEN TOO SELECTIVE IN PROTECTING THE GIFTS THAT WERE PUT ON THIS EARTH FOR OUR USE. WE HAVE CUT DOWN FORESTS, MOVED MOUNTAINS AND WATERCOURSES, GENERALLY DISRUPTING OUR WILDLIFE AND THE TRANQUILITY WE NOW SO EAGERLY SEARCH FOR. WERE WE TENANTS ON THIS EARTH, WE WOULD HAVE BEEN EVICTED AFTER THE FIRST MONTH.

NORTH AMERICANS GENERATE MORE WASTE PER CAPITA THAN ANY OTHER PART OF THE WORLD. WE WERE RECENTLY IN A MIDDLE EAST COUNTRY ASSESSING THEIR WASTE PROBLEMS. FRANKLY, THEIR CAPITAL CITY WITH ITS REFUGEE CAMPS AND THE COUNTRY SIDE IN GENERAL IS FAR CLEANER THAN OURS. THEIR ATTITUDE ALSO IS BROADER THAN OURS AS THEY ARE NOT RELUCTANT TO CROSS THE POLITICAL BOUNDARIES WITHIN THEIR COUNTRY IF IT IS BENEFICIAL. HERE WE FIND NOTHING BUT CONFUSION, RED TAPE AND RELUCTANCE TO MAKE FIRM DECISIONS. IF A SUBJECT IS ONE THAT IS CONTROVERSIAL, THEN THERE IS A TENDENCY TO IGNORE IT.

CONSPICUOUS BY ITS ABSENCE AT MOST INDUSTRIAL CONFERENCES THROUGHOUT CANADA IN THE PAST, HAS BEEN THE SUBJECT OF INDUSTRIAL WASTE DISPOSAL. AS RECENTLY AS APRIL OF THIS YEAR A CONFERENCE WAS CONVENED BY ENVIRONMENT CANADA RE THE RETROFILLING OF TRANSFORMERS. IN THE AGENDA SENT TO DELEGATES IT WAS STATED THAT PCB DISPOSAL WAS NOT TO BE A SUBJECT FOR DISCUSSION. HOWEVER, THE MATTER DID ARISE ON MORE THAN ONE OCCASION, NOT ONLY FROM THE SPEAKERS BUT FROM OTHER CONCERNED DELEGATES FROM THE INDUSTRY.

WASTE MANAGEMENT CANNOT BE SWEPT UNDER THE CARPET ANY LONGER! THE MANUFACTURING INDUSTRY HAS RELIED UPON DISPOSAL COMPANIES TO DISPOSE OF THEIR WASTES. THESE GENERATORS ARE QUICKLY BECOMING AWARE OF THIS COUNTRY'S DECREASING FACILITIES. OUR GOVERNMENTS ARE SWIFTLY CLOSING LANDFILLS, INCINERATORS AND OTHER PREVIOUSLY ACCEPTABLE DISPOSAL SYSTEMS WITHOUT APPARENT CONCERN AS TO WHETHER OR NOT NEW, APPROVED FACILITIES ARE AVAILABLE, OR EVEN BEING CONSIDERED.

THE MATTER OF HAZARDOUS WASTE DISPOSAL SHOULD BE OF EXTREME CONCERN TO OUR GOVERNMENTS. THERE HAVE BEEN PICKET LINES AT SOME U.S. SITES WHERE CANADIAN WASTES ARE GOING AND THIS SHOULD BE A STRONG SIGNAL FOR WHAT IS YET TO COME. THE E.P.A. HAS STATED THAT NO PCB MATERIAL CAN ENTER THE U.S. AFTER JANUARY 1ST, 1979. WE CAN ONLY ASSUME THAT OTHER HAZARDOUS WASTES WILL SHORTLY BE ADDED TO THE LIST.

Our environmental authorities seem to prefer to ignore the clear fact that international doors are closing. Ontario's industry generates a substantial volume of waste and the government must accept the fact that industry requires appropriate disposal sites in this province. The Ontario Environmental Assessment Board, based upon recent decisions, appears to be looking for Utopia and is not prepared to accept proven disposal systems.

We read that the Ministry of Environment advocates that industry should look after its own wastes. How assinine to think that each industry can accomplish such a feat! Can you visualize the chaos that would involve? Think of the number of Environmental Hearings that would be required! Equally important is the number of government inspectors necessary to enforce their Regulations.

If the government however, is referring to the disposal industry, then we ask, "What more can we do?" Both recent attempts to alleviate the crisis in liquid and solid wastes were rejected by Ontario authorities. It is interesting to note that the reasons for refusal in both instances were very similar. We cannot speak with authority concerning the Hearings and the decision for the Maple municipal waste application but we can with respect to the Nanticoke Waste Management proposal.

IN EXAMINING THE ENVIRONMENTAL ASSESSMENT BOARD'S DECISION ONE MUST CONCLUDE THAT THEY MADE THEIR DECISION BASED UPON THE ENVIRONMENTAL ASSESSMENT ACT, AN ACT UNDER WHICH OUR APPLICATION WAS NOT MADE. WE ANTICIPATED APPROVAL SUBJECT TO CERTAIN CONDITIONS BEING MET. WE REALIZED FOR INSTANCE, THAT ADDITIONAL HYDROLOGY WOULD BE REQUIRED. HAD WE BEEN REQUIRED BY THE APPROVALS BRANCH TO SUPPLY FURTHER INFORMATION ON THIS MATTER FOR THE HEARING, IT WOULD HAVE BEEN FORTHCOMING. EACH OF OUR WITNESSES AT THE HEARING WAS SPECIFICALLY ASKED IF ANY FINANCIAL RESTRAINTS HAD BEEN PLACED UPON THEM. THE ANSWER WAS AN EMPHATIC NO!

WE INITIALLY SET OUT TO PROVIDE A FACILITY THAT WAS SECOND TO NONE IN NORTH AMERICA. THE GUIDANCE AND CO-OPERATION OF MEMBERS OF THE VARIOUS DEPARTMENTS OF THE MINISTRY OF THE ENVIRONMENT, WHO DILIGENTLY WORKED ON OUR PROJECT IN CONJUNCTION WITH OUR EXPERTS, IS NOT IN QUESTION. IT IS UNFORTUNATE THEY WERE OBVIOUSLY NOT AWARE OF WHAT IS REQUIRED FOR A HEARING OF THIS NATURE. WE QUESTION WHETHER ANYONE KNOWS. THEIR ENTHUSIASM, AS WELL AS THE ENCOURAGEMENT FROM MINISTRY OFFICIALS THROUGHOUT THE PROVINCE, WAS MOST ENCOURAGING AND STIMULATING TO US. ALSO, THE MINISTRY'S FIELD STAFF COULD SEE A RAY OF HOPE ON THE HORIZON, THAT AT LAST THERE WOULD BE A HOME FOR A BROAD RANGE OF INDUSTRY'S WASTES. TODAY THEY FEEL AS WE DO - KICKED IN THE STOMACH.

WE FAIL TO UNDERSTAND HOW THE APPROVALS BRANCH COULD FIRST OF ALL AGREE THAT THERE WAS SUFFICIENT INFORMATION TO RECOMMEND THAT A HEARING BE CALLED, KNOWING THERE WAS FULL SUPPORT FOR THE PROPOSAL BY THEIR ENGINEERING DEPARTMENT, AS WELL AS THE OTHER MINISTRY WITNESSES AND THEN TAKE A 180 DEGREE TURN, COMPLETELY AGREEING WITH THE ASSESSMENT BOARD'S DECISION. ONE CAN ONLY DRAW THE CONCLUSION THAT SWORN EVIDENCE WAS NOT REVIEWED, NOR WERE MINISTRY OFFICIALS WHO EITHER GAVE EVIDENCE, OR WERE PRESENT, CONSULTED PRIOR TO THE APPROVAL BRANCH'S NEGATIVE DECISION BEING FINALIZED. WE BELIEVE WE WERE LED DOWN THE GARDEN PATH BY WELL-INTENTIONED BUT ILL-INFORMED MINISTRY STAFF.

EVERY ONE OF THE REASONS LISTED FOR REFUSING OUR APPROVAL WAS ADEQUATELY EXPLORED EITHER IN DIRECT EXAMINATION OR RE-EXAMINATION BY OUR SOLICITOR. WE EARLIER MENTIONED THAT ADDITIONAL HYDROLOGY WAS A NECESSITY. SHOULD WE HAVE RECEIVED APPROVAL, WE HAD VOLUNTEERED IN DIRECT TESTIMONY TO SET UP A CONTINGENCY FUND TO BE ADMINISTERED BY THE MINISTRY. WE PRODUCED EXHIBITS INDICATING THAT A FIVE MILLION DOLLAR LIABILITY POLICY WAS AVAILABLE. LINERS HAVE PROVEN SATISFACTORY AND ARE COMPULSORY IN U.S. LANDFILLS BUT IN ONTARIO IT APPEARS THEY MUST HAVE A TRIED AND TRUE HISTORY OF LONGEVITY BEFORE BEING GIVEN A CHANCE TO PROVE THEIR WORTH. HOWEVER, THESE ITEMS ALONG WITH OTHER UNREFUTED EVIDENCE WERE TOTALLY IGNORED. YET THESE VERY ITEMS WERE SOME OF THE REASONS FOR REFUSING APPROVAL. EVEN THE FACT THAT WE PRODUCED A LETTER DIRECTED TO THE LOCAL MUNICIPALITY OFFERING A LEVY, IN ADDITION TO NORMAL TAXATION, WAS TOTALLY IGNORED.

THE ONE SATISFACTION THAT HAS EVOLVED FROM OUR EXPERIENCE OF PREPARING EVIDENCE IN GOOD FAITH AND GOING THROUGH A TRAUMATIC ENVIRONMENTAL HEARING, IS THAT WASTE GENERATORS ARE AROUSED, EXPRESSING THEIR FEELINGS AND CONCERNS TO APPROPRIATE ELECTED OFFICIALS. IT IS DEFINITELY A YEAR OF RESPECT FOR WASTE MANAGEMENT! THE SUPPORT WHICH MEMBERS OF THE CANADIAN MANUFACTURER'S ASSOCIATION GAVE US WAS OVERWHELMING AND SHOULD BE A WARNING SIGNAL TO CONCERNED GOVERNMENTS OF THE CRITICAL SITUATION CANADIAN AND, MORE PARTICULARILY, ONTARIO INDUSTRY NOW FACES. FRANKLY, WE MAY NOT SUCCEED IN OUR APPEAL WITHOUT VIGOROUS SUPPORT AND INDEED, PRESSURE FROM THE WASTE GENERATORS LOCATED IN ONTARIO. WE ARE APPEALING THE DECISION ON THE GROUNDS IT IS CONTRARY TO THE EVIDENCE AND TOO, WE FEEL A STRONG OBLIGATION NOT ONLY TO INDUSTRY, BUT ALSO TO THOSE WHO ARE CONCERNED WITH OUR ENVIRONMENT AND WANT TO SEE THE END OF INDISCRIMINATE DISPOSAL IN ONTARIO.

AND NOW TO DROP THE OTHER SHOE! THERE IS NO WAY THAT DISPOSAL INDUSTRIES WILL VENTURE FORTH IN THE FUTURE INTO THE UNKNOWN FIELD OF ENVIRONMENTAL HEARINGS UNLESS THERE ARE SPECIFIC GUIDELINES. THEY SHOULD ASSURE:

1) THAT THE TECHNICAL INFORMATION REQUIRED FOR A HEARING IS CLEARLY ARTICULATED,

2) THAT ALL THOSE WHO WISH TO SPEAK EITHER FOR OR AGAINST THE APPLICATION BE SWORN AND SUBJECTED TO CROSS-EXAMINATION AS TO THE VALIDITY OF THEIR OBJECTIONS,

3) THAT THE PROPONENT BE PRIVY TO OPPONENTS' TESTIMONY PRIOR TO THE HEARING, AS IS PRACTISED IN COMMON LAW,

4) THAT FRIVOLOUS COMMENTS BE STRICKEN FROM THE TRANSCRIPTS, AND,

5) THAT ENVIRONMENTAL HEARING BOARDS CLEARLY SPELL OUT THE RULES UNDER WHICH THEY PROPOSE TO OPERATE PRIOR TO THE COMMENCEMENT OF SUCH HEARINGS IN ORDER THAT PARTICIPANTS ARE FULLY AWARE OF THE ROLE THEY MUST TAKE.

WE CONCUR WITH THE MEMBER OF THE I.J.C., WATER QUALITY BOARD, WHOSE RECENT COMMENT ESSENTIALLY WAS, "A FEW YEARS AGO WE ENCOURAGED PUBLIC INPUT BUT NOW, HOW DO WE GET RID OF IT?" WE WELCOME THE PUBLIC'S CONSTRUCTIVE CRITICISM BUT TO LISTEN TO THE UNSUPPORTED OPINION AND HEARSAY "GARBAGE" WE WERE CONFRONTED WITH IS BEYOND ALL REASON. IT IS BOTH WASTEFUL AND DISCOURAGING. LET THE PUBLIC PARTICIPATE BUT LET THEM BE READY TO BE SUBJECTED TO QUESTIONING AND PREPARED TO SUPPORT THEIR COMMENTS WITH HARD EVIDENCE. IN OUR OWN CASE, WE OFFERED TO MEET WITH REPRESENTATIVES OF OPPOSING GROUPS BUT NO ONE ACCEPTED THE INVITATION.

INDUSTRY AND OURSELVES ARE NOT THE ONLY LOSERS IN THIS MATTER. THE MINISTRY HAS LEFT A NEGATIVE LEGACY TO FUTURE ONTARIO GENERATIONS TO CLEAN UP THE MESS THAT OUR GOVERNMENT LACKS THE FORTITUDE TO DO. THE "ENVIRONMENTALISTS" OF TODAY WILL BE PAYING THESE BILLS IN THE FUTURE.

To those of you in industry, be patient and do not criticize your local environment inspector. He too is lacking the guidance that should be available. The Acts in Canada are excellent but somewhere along the line the wheels fell off with respect to their interpretations and enforcement. Hardly a day passes that an industry, somewhere in Canada, does not call us concerning a vital problem. Invariably they have been referred to our company by a local environment official. To illustrate further, one government information Ministry telephoned to request our Packaging and Handling Guide for PCB's. Their environment ministry had referred them to us. This should not be! Our people are frequently invited to address groups from public utilities, universities, industry and so forth, on the handling of hazardous wastes because these institutions cannot obtain the facts from government on what should be done, but only what cannot be done.

This is the Year of New Resepct For Waste Management. We say to Provincial and Federal Governments, "If Utopia is not available, then governments should proceed with the best technical knowledge that is available". To industry we say, "Express your concerns to your provincial Minister and federal member of parliament. Tell them the problems you face and ask what their respective governments propose to do in solving the matter."

IN CONCLUSION, WE WOULD ADVISE THAT IT IS OUR INTENTION TO ESTABLISH VIABLE DISPOSAL FACILITIES TO SERVE THE MARITIMES, QUEBEC, ONTARIO AND THE WESTERN PROVINCES. WE ARE NOT PREPARED TO ACCEPT ONTARIO'S NEGATIVE ATTITUDE, BUT WILL PROCEED IN OTHER AREAS WHICH ARE PREPARED TO PROGRESS. IT IS A YEAR OF NEW RESPECT FOR WASTE MANAGEMENT. PERHAPS IT IS NOT RECOGNIZABLE AT THIS TIME BUT THE EVENTS THUS FAR IN 1978 MAY WELL ECHO THROUGH THE YEARS TO COME.

PREPARATION AND CONDUCT OF ENVIRONMENTAL HEARINGS BEFORE THE ENVIRONMENTAL ASSESSMENT BOARD OF ONTARIO

by

M.P. FORESTELL, ESQ., Q.C.

It is my intention in the course of this paper to deal in a very summary way with the essential aspects of preparing for an Environmental Assessment Board hearing for a waste disposal site and for presenting the applicant's position to the Enviornmental Assessment Board during the course of the hearing. It is hoped that these remarks will assist applicants in being successful before the Board. It is, however, with some humility that I make these remarks bearing in mind the Decision of the Environmental Assessment Board in the Nanticoke hearings upon which a great deal of my experience is based. I am sure that you are all aware that the Nanticoke application was unsuccessful, and though unsuccessful, a great deal was learned by myself, by the applicant, and I believe by the Ministry of the Environment.

At the very outset, it is in my opinion essential for a successful application that there be complete trust and faith displayed between the counsel handling the application and his client.

It is essential also that the counsel that is to handle the application be involved from the very beginning of the proposal and that his advice be sought as to the experts who are to be retained and who ultimately will be the witnesses at any Environmental Assessment Board hearing. In this regard, I might mention that in the Nanticoke hearing, I could not ask for a better client than Nanticoke Waste Management Limited and in particular, their President Mr. Drew.

At a very early stage in the proposal, the applicant and his counsel should make careful decisions as to the type of expert that will be required and this will vary depending upon whether it is a secured landfill site or a waste water treatment system. At this stage, the experts such as the hydrologists, the chemists, or the consulting engineers should be carefully screened to ascertain their competence in the particular field and their ability to give evidence in a clear and concise and definite manner. The ability to give their evidence orally as well as in writing is equally important in any Environmental Assessment Board hearing as their technical competence.

Once a proposed site has been selected, bearing in mind the physical requirements of the site, a thorough check of the zoning of the site should be made at the Municipal Offices. If re-zoning is necessary, this should be thoroughly discussed either by the applicant or his counsel, with the Municipal Officials entrusted with the zoning responsibility.

It is at this point that the first tactical decision should be made by the applicant and his counsel, namely, whether to bring an application before the Municipality and ultimately to the Ontario Municipal Board for re-zoning prior to making application for an Environmental Assessment Board hearing. In this regard, hindsight is a wonderful thing for in the Nanticoke application, upon reading the report of the Environmental Assessment Board, it is apparent that it might well have been a better procedure to have proceeded with a re-zoning application through the Municipal Offices and ultimately to the Ontario Municipal Board, prior to going before the Environmental Assessment Board. I must say that this procedure was considered by the applicant in the Nanticoke hearings and the decision made to go to the Environmental Assessment Board because of the time constraints on getting Nanticoke into operation.

It was felt clearly that if the Environmental Assessment Board made a favourable ruling, that the re-zoning would follow much more easily than if there had not been an Environmental Assessment Board hearing. In each individual instance, a decision must be made as to which route will be taken if rezoning is required.

It is essential, in my opinion, that the proposal be well thought out in the conceptual stages prior to any approach to the Municipal councils or the Environmental Ministry Officials. I would further submit

to you that the minute the applicant is ready to present his conceptual proposals to the Ministry of the Environment for their consideration pursuant to The Environmental Protection Act, or for that matter The Environmental Assessment Act, that they at this stage commence their public relations program with the residents of the area in which the liquid or solid waste disposal plant is to be established. In many instances, it would be advisable in my opinion to retain a public relations expert from the area in which you wish to locate.

At this stage, I would recommend that copies of the conceptual plans for the disposal site be presented to the Municipal bodies in the area at a meeting called specifically for this purpose and open to the public. Further, that all news media in the area be given the proposals for dissemination to the general public. Further, the applicant, either on its own or through a public relations expert hired for that purpose, should contact all organizations in the general area such as ratepayers, agricultural groups, fishing groups, and even Church groups and present them with the conceptual proposals, and further should undertake to keep these various groups informed of all developments in furthering the proposed waste disposal site.

As this procedure is being followed, the applicant will, of course, be preparing its final presentation for either the Environmental Assessment Board or the Ontario Municipal Board, and as this final preparation takes place, I would respectfully submit that the final

presentation should be completed well in advance and the information and briefs of the expert witnesses should be typed and distributed to all Municipal bodies in the area, to all organizations that have been previously contacted and expressed an interest in receiving the material.

Negotiations with the various groups should also take place at this time in an attempt to organize a complete exchange of technical information between the applicant's experts and the experts retained by any of the groups that might wish to oppose the location of the site and I think we can assume that there will be groups opposing the location of any waste disposal site.

I should pause at this point in this paper to deal with what is required perhaps for the final presentation before the Environmental Assessment Board. Up until the recent Nanticoke hearing, and the Maple hearing, it was, I think, everyone's opinion including the Ministry of the Environment and the former Minister of the Environment, The Honourable George Kerr, that where the application was under the Environmental Protection Act, 1971, more particularly under Sections 33 and following, that all that was required to be submitted was that degree of engineering completeness as might be required by the Ministry Officials and the Approvals Branch, and that when that had been completed, the Director would request that a hearing be held and that this degree of completeness

would be sufficient for the Environmental Assessment Board. Certainly under the provisions of the Environmental Protection Act 1971, it would clearly appear that only the conceptual approach at this stage would be required, and that the technology would not be required in the final design stage for the purpose of the hearing under the Environmental Protection Act. I think that it is clear from the results of both the Nanticoke hearings and the Maple solid waste hearings that the Environmental Assessment Board is totally and completely ignoring the requirements under the Environmental Protection Act, 1971, and are applying to all hearings the standards required by the Environmental Assessment Act, 1975, even though they do not technically apply, and accordingly, in preparing for any Environmental Assessment Board hearing reference should be made by the applicant to the standard of preparation required by the Environmental Assessment Act and particular reference should be made to Section 5, part 2, of the Environmental Assessment Act which clearly sets forth the very detailed requirements for approval.

In summary, it is my opinion that any applicant should not enter a hearing until his final engineering has been completed almost to the last nut and bolt, if he has any hope of being successful before the present Environmental Assessment Board.

I must state emphatically, however, that such a position

by the Environmental Assessment Board is, in my opinion, an exercise of excessive jurisdiction, and a jurisdiction that the present Board under the Environmental Protection Act does not possess and that the Board has in fact been influenced by the public outcry rather than the Statutes of the Province of Ontario and the policy of the Ministry of the Environment and the Government of Ontario.

With the present attitude of the Environmental Assessment Board towards waste disposal sites, I would venture to suggest to you that they have now, with the recent Maple and Nanticoke decisions, made it virtually impossible for any private applicant or for any segment of the private sector, to afford the type of research and design that will be required to bring any waste disposal site on stream. This attitude by the Environmental Assessment Board will, in my opinion, create a crisis situation for the disposal of hazardous waste in the Province of Ontario and will seriously affect the industrial strength and employment market of this Province.

If, however, an applicant has the courage to do all of the preparatory steps that I have outlined in a summary fashion in this paper, he will then be met with an Environmental Assessment Board hearing and I will now deal with the conduct of that hearing.

Once the hearing date has been set, again I would strongly suggest that the applicant attempt to arrange a meeting between the applicant's experts and the applicant's counsel with the experts that will be called by those parties objecting to the location and establishment of the site, with a hope that by such a meeting the areas that are in dispute between the experts will be narrowed down to such a point that written presentations by the experts may be accepted by the Board as the evidence subject to cross-examination and examination in chief only on those areas that are in dispute. If this procedure is not followed, applicants will, I submit, be faced with hearings that extend for months on end at considerable cost, a cost which is in our opinion not required and is needless.

If the application is strenuously opposed, the first tactic that will be adopted by the opposition is one of delay and for this reason it is absolutely necessary that the successful applicant has distributed all of his material, not only to all bodies that he is required to by law, but to everyone who might be in opposition. The applicant must deprive the opposition of any reason for seeking an adjournment at the opening of the hearing, and any attempt to obtain an adjournment must be vigorously opposed before the Board as it is in my opinion a tactic of opposition to wear down the applicant by delay. During the hearing itself, which will usually be before a three man panel of the Environmental Assessment Board, the applicant should present his case

fully and take absolutely nothing for granted. This may be done either through the filing of written submissions and presenting witnesses for the purpose of cross-examination, or through a combination of written submissions to the Board that are filed andthe calling of viva voce evidence to support these submissions.

Counsel for the applicant must assure that prior to entering any hearing, he has not only read all of the submissions and prepared his witnesses carefully, but he must assure himself that he understands at least in a general way what each of his expert witnesses will say in the witness box.

The conduct of the hearing will be vastly similar to any other court proceeding or administrative tribunal proceeding and the hearing itself will be governed by the provisions of the Statutory Procedures Act and the Judicial Review Procedures Act and I do not intend to deal in detail with these aspects.

I would point out, however, that during the course of the Nanticoke hearing, the Environmental Assessment Board adopted a procedure whereby individual members of the public and in fact some groups of the public, by groups I mean organized groups, where permitted to submit oral representations and written briefs but the applicant's counsel was

prohibited from cross-examining any of these witnesses on either their oral or written presentations. It was our experience in the Nanticoke hearings that many false statements were made in these presentations and that the applicant had no opportunity to counter-act these statements. An example of such a statement was when one member of the public gave evidence before the Board of a dangerous situation existing if there were to be a blizzard in the area and the snowflakes were to touch the top of the waste water treatment lagoon, they would then carry pollution to the surrounding area when the snowflakes were carried by the wind. Certainly, this type of wild statement could, under cross-examination, have been destroyed. The inference given by the Board's attitude in prohibiting cross-examination of these types of witnesses was, during the course of the hearing, as though this evidence was not as important as the evidence given in the witness box under oath and subject to cross-examination, yet on page 12 of the report of the Board in the Nanticoke hearings, in item 11 of the reasons for the recommendations, the Board stated: "The Board weighed the concerns of adjacent residents and landowners and is of the opinion that such concerns are valid, although the technical and engineering concepts of the proposal appear, for the most part, to be satisfactory." Also, commencing at page 108 and through to page 119, the Board deals in detail with that evidence given by the public, where no cross-examination was permitted. This, in my opinion, constitutes a denial of natural justice to the applicant. Finally, in conclusion, I should like to strongly suggest to this group that a very

strong lobby for changes by way of legislation to the hearing process of disposal sites be undertaken. Among the things that this group, in my opinion, should press the Government strongly for is:

1. the elimination of the necessity of both an Ontario Municipal Board hearing and an Environmental Assessment Board hearing;

2. legislating the requirement that expert evidence of both the applicant and opposing experts be exchanged well before the hearing, much in the way of the examination for discovery procedures adopted by the Courts of this land.

I should also say in conclusion that throughout the early stages of the Nanticoke application, the Ministry of the Environment under its former Minister, The Honourable George Kerr, expressed concern for the necessity of disposal sites for hazardous waste to be located in the Province of Ontario and without in any way destroying their role in protecting the environment of Ontario, encouraged the applicant, Nanticoke Waste Management Limited, to proceed with a proposal for providing those facilities in a manner which was found by the Environmental Assessment Board to be technically sound, and even with this encouragement the Environmental Assessment Board who found that the proposal was technically sound, decided to reject the proposal. This decision was followed almost verbatim by the Director of Approvals, Mr. Caplice, when in fact a complete reading of the transcript would have revealed to the Director that the Nanticoke proposal was in fact a sound proposal that would have provided the Province with an environmentally safe disposal

SOLIDIFICATION OF WASTES

by David Krofchak, P.Eng.

Solidification is the term which defines, in one word, the activity in which loose materials or liquids or sludges or combinations of these things "become solid" hard, firm or compact or are brought together in unity.

Everyone would agree that the earth's crust is formed of solid materials in general, not-with-standing the water in the lakes, seas and swamp areas. The soils are largely composed of silicate compounds. In fact, it has been estimated that up to 80% of the earth's surface or soils are composed of complex silicate compounds.

The importance of this is appreciated when it is realized that nearly all toxic pollutants originated from soils rich in various elements which, due to this, are defined as mineable ore! An ore rich in say copper is mined for its copper value, of course, and the copper in turn is converted into numerous copper compounds some of whih invariably end up in wastes such as plating wastes. Applying this particular example to the Solidification Technology we would devise a way to convert the copper bearing wastes into a copper silicate compound, because in this form, the copper is insoluble in water and, therefore, non-toxic and a solid material not unlike a solid copper bearing soil or ore.

The complexity of solidification can be appreciated when one considers that to treat wastes into a form which can be solidified requires an extensive knowledge of chemistry. To take the treated wastes and convert them into typical silicate compounds analogous to soils requires a knowledge of geochemistry. To set up a practical process to carry out the steps to accomplish solidification requires a knowledge of chemical engineering and to tackle some of the huge problems of the world such as mine tailings requires the approach of civil engineering in order to execute the work in the realms of viable economics. All these disciplines must be recognized and used to make solidification of wastes a practical reality rather than a laboratory curiosity.

The history of solidification has to be traced back in retrospect by analogy to things that were done for specific purposes and, in fact, were not recognized as solidification in the context as outlined in this paper. For instance, the Romans found out that if they took lime, sand, stone and volcanic cilica ash they could make concrete or synthetic stone. Modern concrete is Portland cement which is tri-calcium aluminum silicate. ($3CaO\text{-}Al_2O_3\text{-}SiO_2$). While this is a simplification of the formula it serves to illustrate that it is a silicate compound. Most of the earth's sedimentary rocks are complex mixtures of silicate compounds.

Typically silts formed sediments which, in turn, became clays, mud stones, shales, and sand stones. A cataloguing and analysis of all the different kinds of sedimentary rocks that exist on the earth in terms of the chemical structure would be an impossible task filling countless volumes of books and indeed whole libraries.

So what is the point of all this and what does it have to do with toxic wastes? Well, any combination of toxic wastes (excluding insoluble organics such as oil, gasoline and solvents) can be converted to sediments which, in turn, can be reacted into silicate compounds and become a solid material analogous to a soil or indeed a soil in its own right. Accomplishing this means that the waste is no longer a toxic substance to the environment.

This whole procedure is called solidification and has been patented. The title of the patent is "The Stepwise Treatment of Waste liquids, sludges and materials to form Solid Silicates". (Reference No. 1)

Silicate chemistry is a vast and infinite subject based on the silicon atom. It is remarkable that the elements, silicon and carbon, which resemble each other in so many respects, should play such different roles in living things.

Many mysteries exist in the world regarding explaining how certain large quartz crystals could have been formed when its virtual insolubility in water is appreciated and further, how was petrified wood (i.e. wood replaced by silica) formed? These and many other examples cannot as yet be duplicated in the laboratory. It would appear that nature has nailed down silicate chemistry in dramatic ways taken for granted in the world and here we are now struggling to invent ways to form wastes into silicate soils similar to that which nature has done very effectively with the elements over the millenniums.

Based on this background, a major attack has been made on applying solidification to a large percentage of the liquid wastes hauled out of industries in Ontario. In 1976, a commercial sized pilot run and test was done in conjunction with and for the Ministry of Environment of Ontario. (See Reference No. 2)

This test was done on mixed wastes collected from all manner of industries. These tests were successful and resulted in a proposal being made to set up a large test site in Hamilton, Ontario. The site was completed in March 1977 and solidification of large volumes of wastes from all of the industries in Hamilton started in April. Over 350,000 gals. per month of wastes have been solidified since April, 1977. One month over 890,000 gallons was solidified.

The solidified material is used as soil cover for the garbage at the sanitary landfill site in Hamilton, Ontario, and at the present rate of "soil" production, it will take 25 years to cover the site.

In order to obtain an independant evaluation of this solidification application suitable for assisting in obtaining final approvals for the site and for other engineering and scientific reasons, a test program was designed by Dr. Bob McAndrew of the University of Toronto, Department of Metallurgy and Material Science. (See Reference No. 4) This work was carried out during the period of July – December, 1977. Over 25 leaching tests were conducted on 10 solidified product materials produced at the site and chemical analysis of over 90 liquid and solid samples requiring over 2,000 assay determination of individual elements were made. The conclusions from this test work were:

1. All samples gave similar results to each other with respect to low levels of leachability of toxic elements.
2. Total elements leaching out individually was generally less than 1 ppm.
3. The materials as solidified would meet all present environmental standards.
4. The solidified materials looked liked typical soft brown clay/shales.

This is a major program which is still ongoing. The following descriptions and results were obtained from Dr. McAndrew's report.

The solidification process used in the test is proprietary and, therefore, only general process information is described. The solidification technology is covered by Canadian Patent No. 1024277 (issued 10th of January, 1978). Patents have been applied for in the U.S.A. and other countries. (Ref. No. 1 and No. 3).

In general, the test operation, consisited of the following steps:

1. Liquid waste received from various industrial sources by tank truck was unloaded into either of two 125,000 gallon holding lagoons. A third lagoon was used to blend 100,000 gallon lots of liquid waste prior to solidification treatment.

2. Solidification was done in 3,500 gallon batches. Alkaline and silicate reagents were added, in the required amounts, to the liquid waste in a blender and the resulting slurry was fed to the reaction tank.

3. When the mixing and initial solidification reaction was complete, the batch of solidified product was transferred by dump truck to a temporary storage pile for several days to allow initial curing prior to being moved in the final land fill site.

4. Each 100,000 gallon lagoon lot required 25 – 30 batches which were completed during a 3 – 4 day period. Liquid waste disposal required solidification of 2 – 4 lots per month during the summer of 1977.

Ten samples of solidified product were evaluated in the testing program. Seven were field samples of material produced at the Hamilton site while three additional samples were prepared in the laboratory. The stability of these product samples with respect to environmental attack by aqueous solutions was evaluated in a series of 25 leaching tests in the laboratory. These tests included both continuous flow leaching in glass columns, and constant volume leaching in stirred beakers and shaking flasks. The column leaching tests were run for 8 – 26 days while the constant volume leaching tests were run for 9 – 13 days.

Chemical analyses were provided by Barringer Research Ltd., using a Multielement Radio Frequency Induction Coupled Plasma Emission Spectrometer.

Results

All samples tested gave similar results to each other in both the continuous flow column tests and in the constant volume shaking flash tests. Table 1 gives chemical analysis for a series of samples collected during a column test operated for 16 days at room temperature using tap water. The solidified product (3SP) was collected from the daily production at the Hamilton site on August 23rd, 1977.

Table 2 gives similar chemical analyses for shaking flask tests using the 3SP solidified field sample (Test 20b) plus two other solidified products prepared in the laboratory. The 11 SP laboratory material was produced using a sample of the original liquid waste (3LW) (Test 27b). The 10SP laboratory material was produced using the liquid waste (3LW) with higher concentrations of As, Cd, Co, Cu, Hg, Mo, Ni, Pb and Sb as shown for sample (3LWS) (Test 27a).

Also shown in Table 2 are the results from a shake flask test using a tupical clay and soil mixture used for final cover on the land fill site. The results are essentially the same for the clay and soil mixture as they are for the solidified product material.

Discussion

The following general observations were made:

1. The concentration of individual heavy metals was generally less than 1 ppm and reached constant equilibrium or steady state values within several days. These elements include Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Ti, V and Zn.

2. The steady state values were slightly different for different tests depending on the sample origin, column bed depth and bed permeability. The column bed depths were in the 10 – 20 cm range and bed permeabilities were found to be in the range $2 - 6 \times 10^{-5}$ cm/sec. which is also typical for nature soils.

3. The concentration of other elements also reached constant values which were generally less than 1 ppm. These elements include Al, B, Ba, Mg, and P. All solutions contained Ca in the range 600 – 1,000 ppm which is typical for calcium saturation.

4. Alkali metals originally present in the waste liquids leached out relatively quickly (1 – 2 weeks) from the solidified product. Thereafter, the alkali metal concentrations remain constant and equal to the concentration of the water used in the column leaching tests (i. e. 20 – 25 ppm Na_3 2.3 ppm K).

5. Based on measured bed permeability and steady state equilibrium concentrations estimates can be made of the time required for complete dissolution of each element. For example, using an average annual rainfill of 80 cm/year, the time for complete dissolution per centimetre of bed height would be:

e.g.	Zn	20,000 years
	Cd	140 years
	Ca	2.1 years

The actual chemistry by which the metal impurities are tied up by solidification is complex and probably involves the formation of some or all of the following: hydroxides. sulphates, carbonates, and silicates as well as other compounds. In their initial form, these precipitates, like all precipitates, are in their least stable or most soluble form. These active forms tend to convert to more stable forms through internal structural reordering. Aging or curing therefore should result in more stable and less soluble precipitated material.

Studies are continuing with the objective of defining, in more detail, the chemical and physical structure of the final solidified product material. The methods being used include x-ray diffraction, scanning electron microscopy with an X-ray fluorescence probe, thermal gravimetric analysis and differential thermal analysis.

TABLE 1 – RESULTS OF COLUMN LEACH

	Solidified Product 3Sp	LEACHATE SAMPLES 3CL2	3CL3	3CL4	3CL7	3CL10	Tap Water
Time, days		0–5	5–7	7–9	12–13	15–16	
Sample, mls		150	78	31	36	35	
pH		8.4	10.8	10.2	10.5	----	7.3
Assay, ppm							
1. Aluminum (Al)	27400	.3	.6	.2	.2	.2	.04
2. Arsenic (As	----	----	----	----	----	----	----
3. Barium (Ba)	170	.3	.1	<.08	<.08	<.08	<.02
4. Boron (B)	----	1.0	.8	.4	.3	.2	.95
5. Cadmium (Cd)	118	<.1	<.1	.1	.1	.1	<.1
6. Calcium (Ca)	165000	900	580	570	630	630	.56
7. Chromium (Cr)	880	.22	.09	.05	.01	<.01	<.01
8. Cobalt (Co)	26	<.02	<.02	.02	.02	.02	.16
9. Copper (Cu)	61	.33	.14	.11	.05	.05	.03
10. Iron (Fe)	52600	.02	.08	.02	.04	.01	<.005
11. Lead (Pb)	----	<.5	<.5	<.5	<.5	<.5	----
12. Magnesium (Mg)	8400	.47	.34	.36	.05	.02	3.4
13. Manganese (Mn)	750	<.001	<.001	<.09	<.04	<.08	.07
14. Mercury (Hg)	----	----	----	----	----	----	----
15. Molydenum (Mo)	----	1.60	.78	.59	.05	.02	.13
16. Nickel (Ni)	144	<.1	<.1	<.1	<.1	<.1	<.02
17. Phosphorous (P)	1120	<.5	.5	.8	.8	.9	<.1
18. Potassium (K)	----	4	3	2	2	2	2
19. Sodium (Na)	7600	1280	68	41	25	22	22
20. Silicon (Si)	183000	4.5	4.5	2.8	1.8	1.6	.56
21. Strontium (Sr)	190	1.2	.87	.73	.87	.90	.19
22. Titanium (Ti)	1810	.001	.001	.004	.006	.005	.002
23. Vanadium (V)	52	<.01	<.01	<.01	<.01	<.01	.02
24. Zinc (Zn)	42800	<.01	<.01	<.01	<.01	<.01	<.01

TABLE 2 – COMPARISON OF SHAKE FLASK TESTS

	Liquid Waste 3LW	Doped Waste 3LWS	Tap Water	Field 3SP Filtrate 3FL	Lab 11 SP Filtrate 11FL	Doped 10SP Filtrate 10FL	Clay Leach	
							Clay 3 CLY	Filtrate 3 CLY
Charge Wt, g				50	50	50		50
Water, ml				100	100	100		100
Time, days				9	9	9		17
Final pH			7.3	10.5	10.5	10.2		8.0
Assay, ppm								
1. Aluminum (Al)	32	50	.04	<.1	.4	.6	60000	<.1
2. Arsenic (As)	--	28	--	--	--	.02	----	--
3. Barium (Ba)	0.2	314	<.02	.08	<.05	<.05	410	<.08
4. Boron (B)	--	46	.95	.14	.08	.10	----	.30
5. Cadmium (Cd)	23	228	<.1	<.1	<.1	<.1	<.1	<.1
6. Calcium (Ca)	672	514	.56	880	2620	2790	110000	137
7. Chromium (Cr)	1740	1480	<.01	<.01	<.01	<.01	<.01	<.01
8. Cobalt (Co)	3.5	193	.16	.02	.06	.16	13.7	.19
9. Copper (Cu)	12	224	.03	.27	.52	.67	30.2	.05
10. Iron (Fe)	22200	19500	<.005	<.005	<.005	<.005	29000	<.005
11. Lead (Pb)	<.1	9	--	.3	.26	.26	<.2	.3
12. Magnesium (Mg)	90	135	13.4	.9	<.001	<.001	10300	16
13. Manganese (Mn)	277	161	.07	<.001	<.001	.001	727	.13
14. Mercury (Hg)	--	152	--	--	--	<.0003	--	--
15. Molydenum (Mo)	.71	270	.13	.96	.86	36	<.02	.18
16. Nickel (Ni)	83	217	<.02	<.1	.2	<.1	24	<.1
17. Phosphorous (P)	171	136	<.1	<.1	<.1	<.1	490	.9
18. Potassium (K)	41	9	2	--	41	27	--	--
19. Sodium (Na)	923	2720	22	1140	3750	1350	8500	36
20. Silicon (Si)	30.2	47.4	.56	.91	.83	1.2	--	6.5
21. Strontium (Sr)	2.5	3.9	.19	1.4	3.5	5.0	246	.23
22. Titanium (Ti)	3.4	4.3	.002	<.001	.03	.04	3290	.01
23. Vanadium (V)	2.3	.76	.02	<.01	<.01	<.01	87	.02
24. Zinc (Zn)	28100	15900	<.01	<.01	1	1	<.01	<.01

We maintain a 6,000 sq. ft. laboratory and sample library for solidification and it is run by a qualified geochemist. Virtually every day, some sample of waste from the North American Continent is solidified along with other ongoing test programs.

As the enormous size of the subject of solidification has unfolded, searching questions have understandably arisen. One of which has been the very nature of the silicate and other compounds linking the particles together. To this end, we have commissioned the Eitel Institute of Silicate Science through it's director, Professor William Kneller, Ph. D. to conduct in-depth studies aided by Electron Microscopy and X-Ray Difraction methods on specific solidified samples. To date the tests shown on these samples studied, that the compounds formed by the solidification process are, in fact, silicate compounds. Work is proceeding to identify the specific silicate compounds in various samples.

The following shows an example of an electron microscope study of a sample of uranium mine tailings before and after solidification and you will note the definite well formed crystal growth shown in the solidified sample.

The analyses of the cementious material illustrated in the text show a compound similar to that of hydrogarnet or hydrogrossular ($Ca_3Al_2Si_2O_8(SiO_4)_{1-m}(OH)_{4m}$). Other compounds which may be present, but have not been confirmed, are similar compositionally to gehlenite or hardystonite, both of which are silicate compounds.

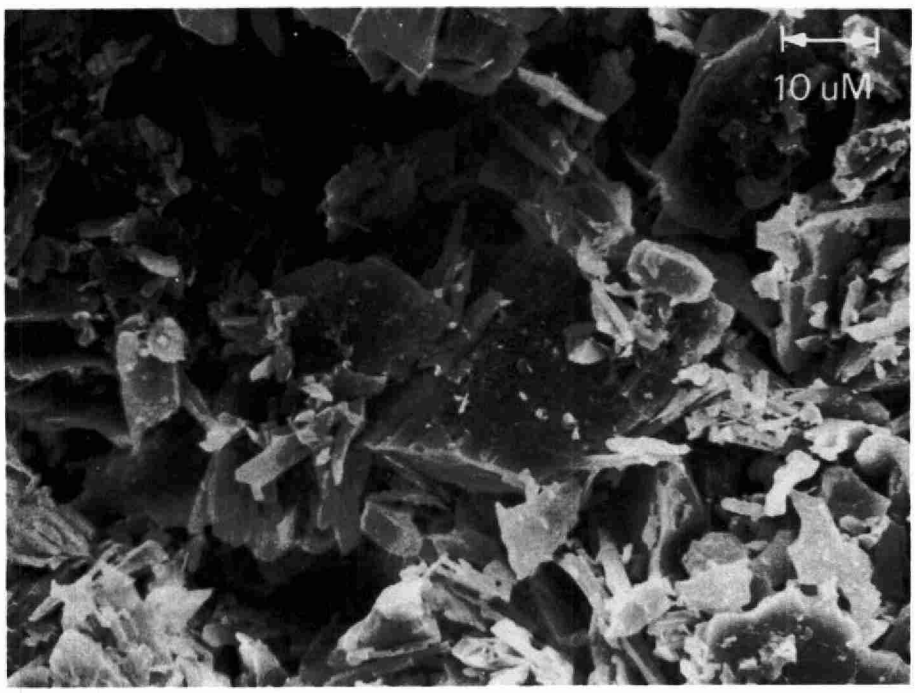

Photo No. 1
Untreated Tailings of Denison Mines
Secondary Filter Cake

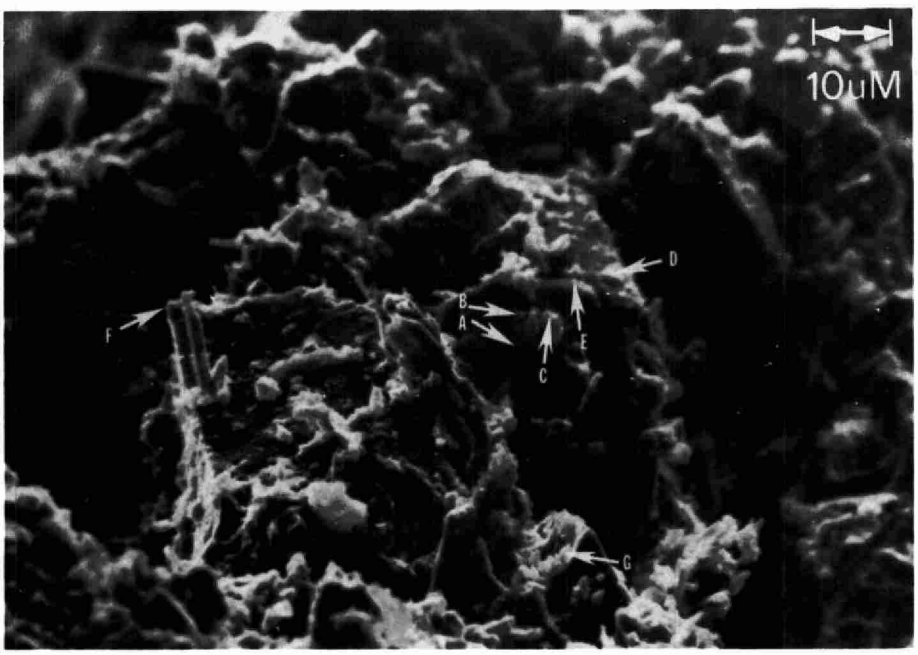

Photo No. 2
Solidified Denison Mines Tailings
Secondary Filter Cake

Photo No. 3

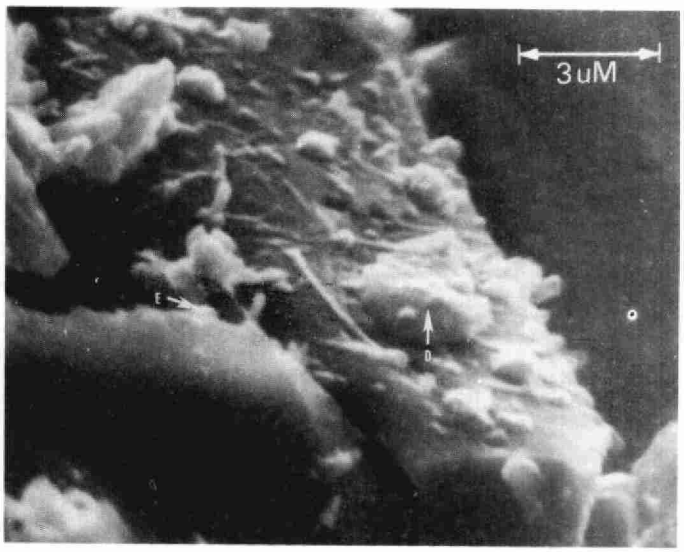

Photo No. 4

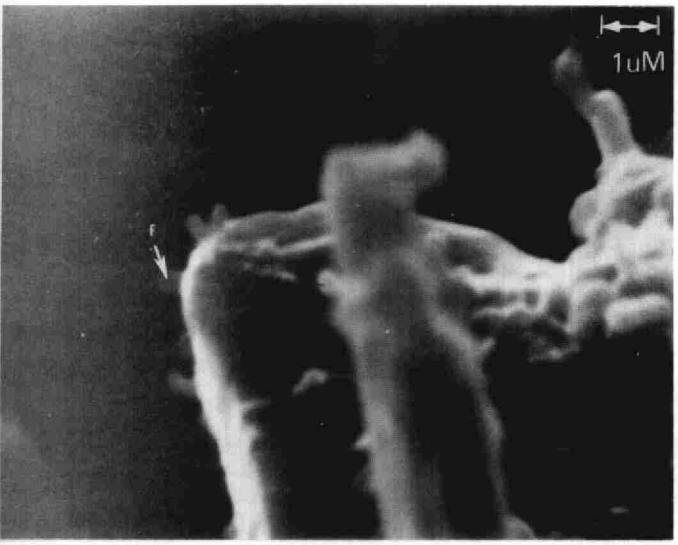

Photo No. 5

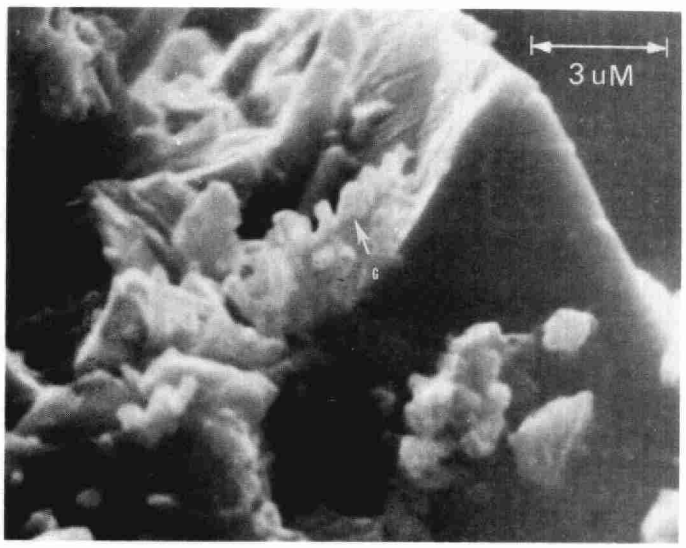

Photo No. 6

Photos No. 3, No. 4, No. 5 and No. 6 are close-ups of the points A, B, C, D, E, and F marked by the arrows on photo No. 2.

In compairing photo No. 1 with No. 2, it will be at once observed that the unsolidified tailings show as clearly defined borken rock fragments and crystals.

Photo No. 2, the solidified tailings, has numerous growths on and between the crystals and rock fragments. On some of the new material observed, we marked the points A, B, C, D, E and F and called for the electron microscope to zero in on these points as shown in photos 3, 4, 5 and 6, and take a dispersive x-ray analysis of the new material at these 5 points. The purpose of this being to determine the composition of the new material that has been formed and is holding the tailings together as a sedimentary rock.

The analysis of points A, B, C, D, E and F are tabulated as follows:

Point	Na%	Mg%	Al%	Si%	S%	K%	Ca%	Fe%
A	2.09	0.17	0.25	2.43	19.98	0.19	28.39	0.45
B	1.33	1.09	0.49	9.13	3.63	0.30	37.22	0.78
C	1.91	0.65	0.59	5.12	17.93	0.16	26.63	0.99
D	2.21	0.40	2.31	46.77	0.12	0.06	1.23	0.86
E	1.31	1.60	2.38	36.68	1.89	1.11	7.38	1.58
F	1.65	3.16	5.86	23.85	3.27	4.57	8.07	3.54

At this stage in Dr. Knellers research indications are that the silicates present in the cement are an admixture of sulphates, aluminates, sulpha-aluminates and silicates. The particles located at Points A and C are most probably calcium sulphate with other minor chemical phases being present. Points D, E and F appear to be silica rich. Point D might be a partially crystallized silica gel, whereas Points E and F might be true complex silicate compounds.

As further evidence of the validity of the above results, we have taken samples of the solidified tailings and immersed them in water for prolonged periods of time (several months) and they did not collapse or fall apart as would be the case if the Na, Mg, SO_4 and K was not tied up as an insoluble silicate.

If the unsolidified tailings are dried, they become hard but on immediate contact with water, they collapse into a flowable mud, sludge or slime and this happens regardless of how often this is done. Thus, these tailings, untreated, are never stable.

In the case of mixed hazardous wastes containing all kinds of metals in solution such as Cu, Cr, Ni, Cd and Fe, etc., these metals are first precipitated and the resultant sludge is reacted with an active silicate to form the mass into a solid silicate as a complex metallic silicate.

Applications of Solidification:

The technology of solidification is a very large subject spanning most major industrial endeavours. Of particular importance are:

1. Industrial Wastes such as sludge, dusts and other materials.
2. Mining Wastes such as the problems of tailings disposal and all manner of other wastes associated with mining and the backfilling of mines.
3. Civil Engineering applications such as dredging, land reclamation and stabilization of of soils and earth dams, etc.
4. Municipal Sewage such as the disposal of sewage sludge and the improvement of sewage treatment plant techniques.
5. Special Applications: There are numerous world scale problems which because of their size and complexities require separate categorization. Some examples of these are:
   - The Great Canadian Athabasca Tar Sands
   - The Florida Phosphate Mines which produce 30% of the world's phosphate fertilizers.
   - Coal mining produces large quantities of coal dust which, when solidified, could become saleable coal.
   - Large industrial in-house wastes have to be dealt with by specially designed schemes and programs utilizing various wastes available to reduce the cost of total pollution control and produce a useful end material such as high grade land fill, road sub-base, or in the case of steel mills, a possible feed for blast furnaces.

It is expected that solidification based on silicate chemistry will find a growing and permanent place in the array of modern technology as applied to not only environmental problems but to many commercially important items such as mine backfill, recovery of coal dust and production of road base, etc.

Conclusions

The work-to-date on the solidification of wastes based on a stepwise treatment of wastes to form solid silicates has proven itself both in the laboratory and on full scale applications in the field. It is now known that the various steps to accomplish this vary for each mixture of wastes – once the formulation has been determined and a solid silicate matrix or compound formed, the final material resembles a typical soil such as soft fine grained shale, mudstone or sandstone.

An interesting aspect of this work is that while, for years, we have worked at solidifying various wastes and considered it a solution to that particular waste problem, and it is only recently that it was realized that the solidification technique and processes were, in fact, a way of accelerating geochemical processes which have taken centuries to accomplish the same thing. e.g. the formation of the sedimentary rocks.

In other words, since the constituents of most wastes originated from the earth in rocks, mostly associated with silicates, we have reformed the wastes back into a silicate soil in the form of a silicate sedimentary rock. This being the case, there can be no doubt as to solidification being a permanent and ultimate solution to many hazardous waste problems.

References

No. 1 Canadian Patent No. 1024277 entitled "The Stepwise Treatment of Aqueous Wastes to Form Solid Silicates", Inventor David Krofchak, Issued 78.01.10.

No. 2 An Assessment of a Process for the Solidification and Stabilization of Liquid Industrial Wastes, 1976 by the Ontario Ministry of the Environment, Industrial Section, Pollution Control Branch.

No. 3 Patents have been filed in most foreign countries including the U.S.A. As of this date, the patent has been granted and issued in Canada (see Ref. No. 1) and just recently, in the U.S.A. The Patent in the U.S.A. was allowed on April 10th, 1978.

No. 4 Preliminary Report on the Technical Assessment of a Solidification Process for Treating Industrial Liquid Wastes by R. T. McAndrew, Ph.D., P.Eng., Jan. 1978